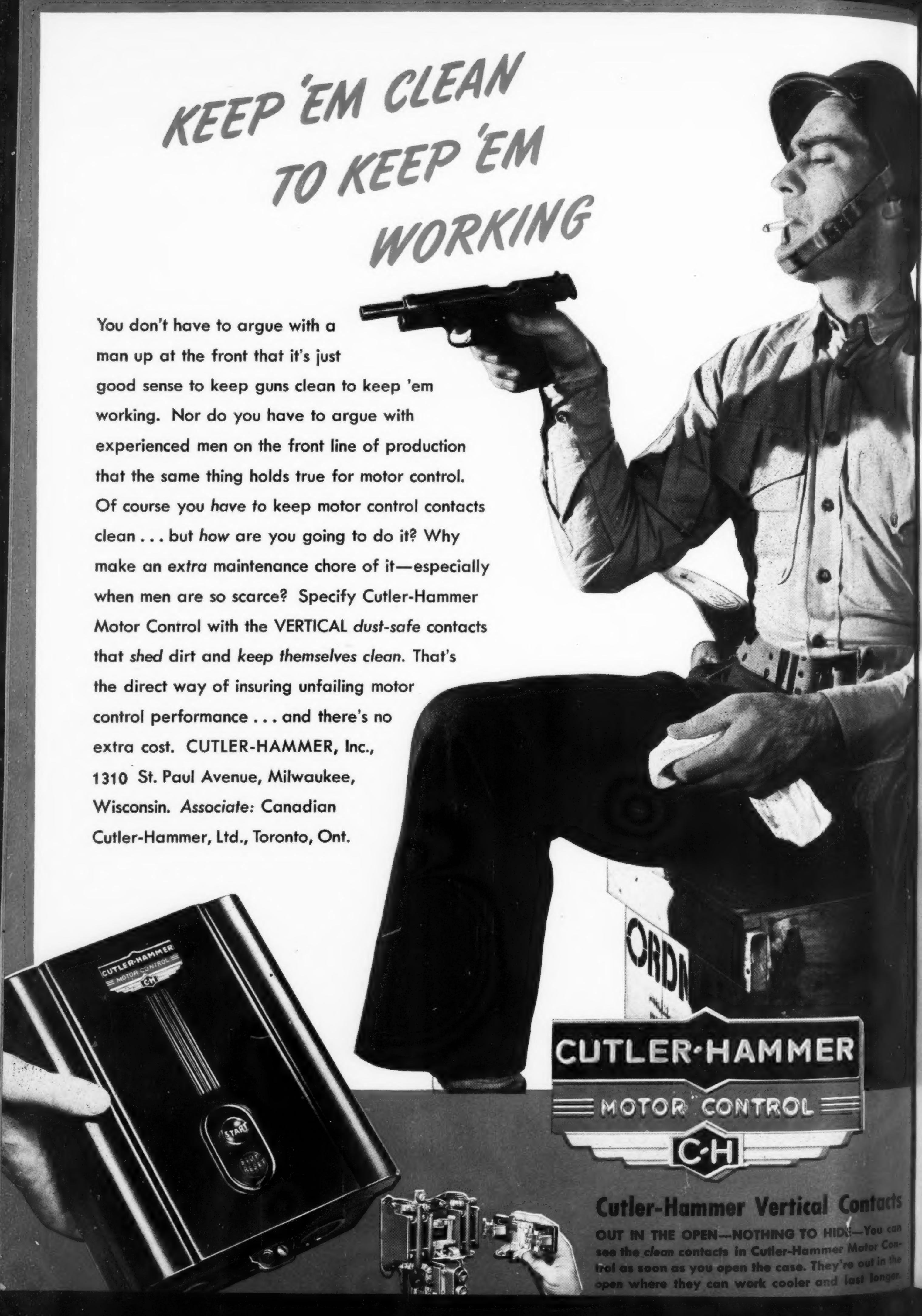

MACHINE DESIGN
February 1943
In This Issue:
Designing a Gear Finisher
Applying Forgings in Machines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MACHINE DESIGN

Volume 15 FEBRUARY, 1943 Number 2

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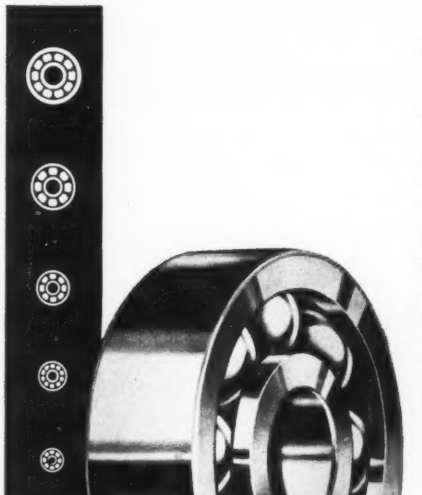

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Topics

AMERICA'S first military transport plane built almost entirely of wood by Curtiss-Wright recently completed a successful test flight. Combining molded plywood, laminates and plain lumber, the plane is produced largely by subcontract to the woodworking industry. Known as the Caravan, it is a high-wing monoplane with a wing span of 108 feet, a length of 68 feet and two 1200-horsepower engines.

♦

IN THIS year the United States should reach a peak in aluminum production which the entire Axis nations combined cannot hope to achieve. During the past year we produced this vital warplane metal at a greater rate than all Nazified Europe and probably eight times faster than Japan.

♦

COLOR coding to assure that machine elements receive the proper grade of lubricant has been requested by WPB. In this way costly mistakes might be avoided and machine maintenance facilitated. For example, the oil cap on the spindle bearing of a grinding machine could be painted red and the same color used to mark the container holding the spindle oil.

♦

POWDER metals applied in the form of metal cladding show promise that virtually any metal can be clad on steel. Already successful for certain alloys with fairly low melting points, new developments indicate that the method will have far-reaching applications.

♦

URGENCY for simplifying the nation's war production job because of increasing use of unskilled labor, acuteness of the industrial manpower situation, and need for conserving materials to the utmost have caused the American Society of Tool Engineers to reverse its previous decision not to hold an exhibition in 1943. Thus, simplified exhibits bearing directly on the immediate job of expediting war production will be shown in conjunction with the society's annual meeting in Milwaukee.

♦

BECAUSE space and weight are limited in modern aircraft, direct-current distribution systems for auxiliary power probably will give way to alternating-current units. Advantage of the a-c current system is that it allows transmission at higher voltage, utilizing transformers where needed and saving considerable copper. Some power units operate better on alternating than on direct current. Where direct current is required, however, rectifiers may be employed. Considerable work also is being done on high-frequency power because it promises better performance at high altitudes. Since power units would operate at higher speeds, further weight reductions would be possible.

♦

THAT output of essential minerals be not slowed down, it may be necessary to set up WPB control through mandatory scheduling of mine machinery production and delivery, both for domestic use and lend-lease purposes, according to Arthur S. Knoizen, Director of WPB's mining equipment division. "Through such scheduling we hope to achieve maximum utilization of materials, facilities and manpower."

♦

SILICON bronze with some zinc content and no tin has recently been recommended to replace phosphor bronzes and gear bronzes that normally contain considerable tin. It has tensile strength of 40,000 to 50,000 pounds per square inch, elongation 15 to 23 per cent, brinell hardness 90 to 125 and specific gravity 8.44. Castings will withstand high liquid pressures and are corrosion resistant.

♦

WACO nine-place cargo glider has proved itself satisfactory in every detail and is now in mass production. Manufacturing rights have been granted to a score of other airplane manufacturing companies to expedite production. Similar craft are also being built as fifteen-place gliders, carrying fifteen fully equipped fighting men or their equivalent in cargo.

♦

RESEARCH work on synthetic rubbers has been expanded to include top ranking scientists at three engineering colleges. In a new working arrangement between Case School of Applied Science, Princeton University, Ohio State University and Firestone, the colleges will study the lesser known phases in an attempt to improve upon the properties of the various synthetics. In this arrangement, all records and information of the Firestone company will be available to carry the work forward at top speed.

MACHINE DESIGN

Gear Finisher Design Provides for Subassembly

By H. Pelphrey
Research Engineer
Michigan Tool Co.

LARGELY resulting from the war program, need for accurate finish of large gears has vastly increased. While machines for finishing gears up to 18 inches in diameter to close limits have been widely used for many years, the demand for increased production to similar accuracies in larger gears has introduced new problems in the design of machines for gear finishing. Because the methods used in solving some of the important problems involved are applicable to the design of machines for other purposes, the following study of the design of a machine for finishing large gears by the crossed-axis shaving method is of special interest.

In the rotary crossed-axis shaving method a grooved toothed cutter is revolved in mesh with a gear, previously cut with a small amount of stock left for finishing. The helix angle of the teeth on the cutter differs from that of the gear so that when the cutter is mounted at a "crossed-axis" angle corresponding with the difference in helix angles between the two, a cutting or shaving action is produced.

To obtain desired results in any shaving machine, especially at high production rates, rigidity throughout the machine is essential. Simplicity of operation is also important since the machine must be operable by relatively unskilled labor. Versatility is a third factor to be considered, so that changes in parts or a wider variety of sizes can be handled with minimum resetting of the ma-

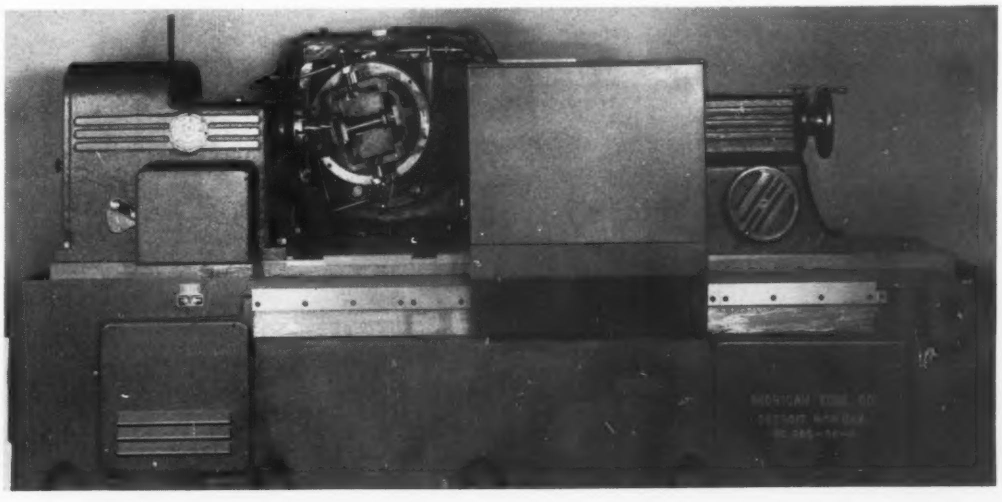


Fig. 1—Gear finisher produces accuracies on large gears similar to those required on small ones. Electrical controls simplify mechanical design and provide versatility in operation

chine with least shut-down time.

A machine in which these essentials have been incorporated is shown in *Fig.* 1. It provides three methods of finishing gears ranging in diameter from four inches to three feet, with face widths up to 20 inches, either when mounted on shafts or not. The gear is mounted between either of two sets of centers depending upon gear diameter and upon the length, weight and rigidity of the shaft. Rotation of the gear drives the cutter, which is mounted on a spindle attached to a cutter head. The head in turn is mounted on slides which permit vertical and transverse movements of the cutter. The entire assembly is mounted on a slide which provides the feed of the cutter into the gear. The three shaving methods are obtained by various settings of the machine in which the vertical and transverse movements of the cutter slides and the infeed are combined in different ways. A wide variety of speeds is also provided so that advantage can be taken of the method used to give maximum production capacity.

To obtain rigidity and accuracy without penalizing speed of operation, the design of driving-spindle mounting and spindle drive shown in *Fig.* 2 was evolved. Previsions in design are made so that the holes for both the spindles can be bored in a single setting of the housing on the boring machine and so that metal surrounds the spindles for their entire length between mounting bearings. The housing sections are thick and provide a rigid support for both ends of the two spindles.

Another feature of the spindle design provides for bench assembly of the bearings, spacers, and nuts on the spindles. Thus the location and snugness of the bearings can be checked before the spindles are installed. At the work end, three single-row combination radial and thrust bearings are mounted to form "1½ sets," the inner bearing of the three being spaced some distance away from the other two. The outer two take inward thrust in tandem, whereas the inner bearing takes outward thrust.

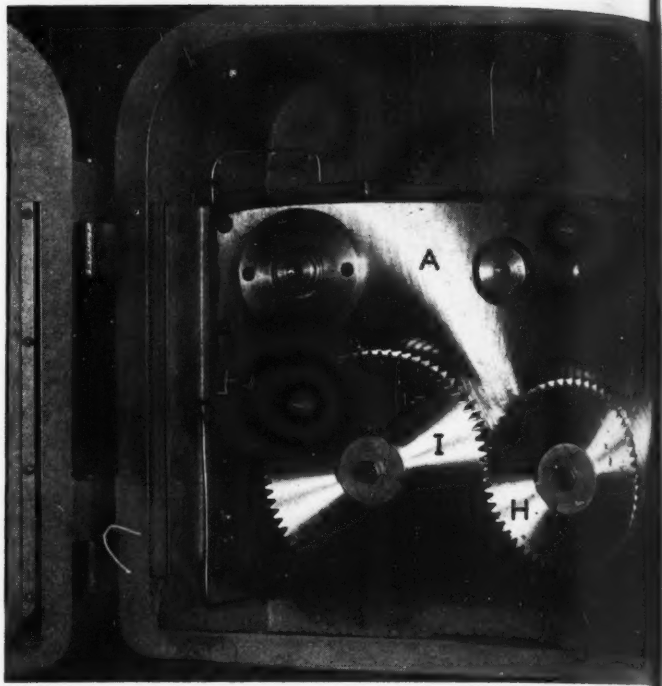
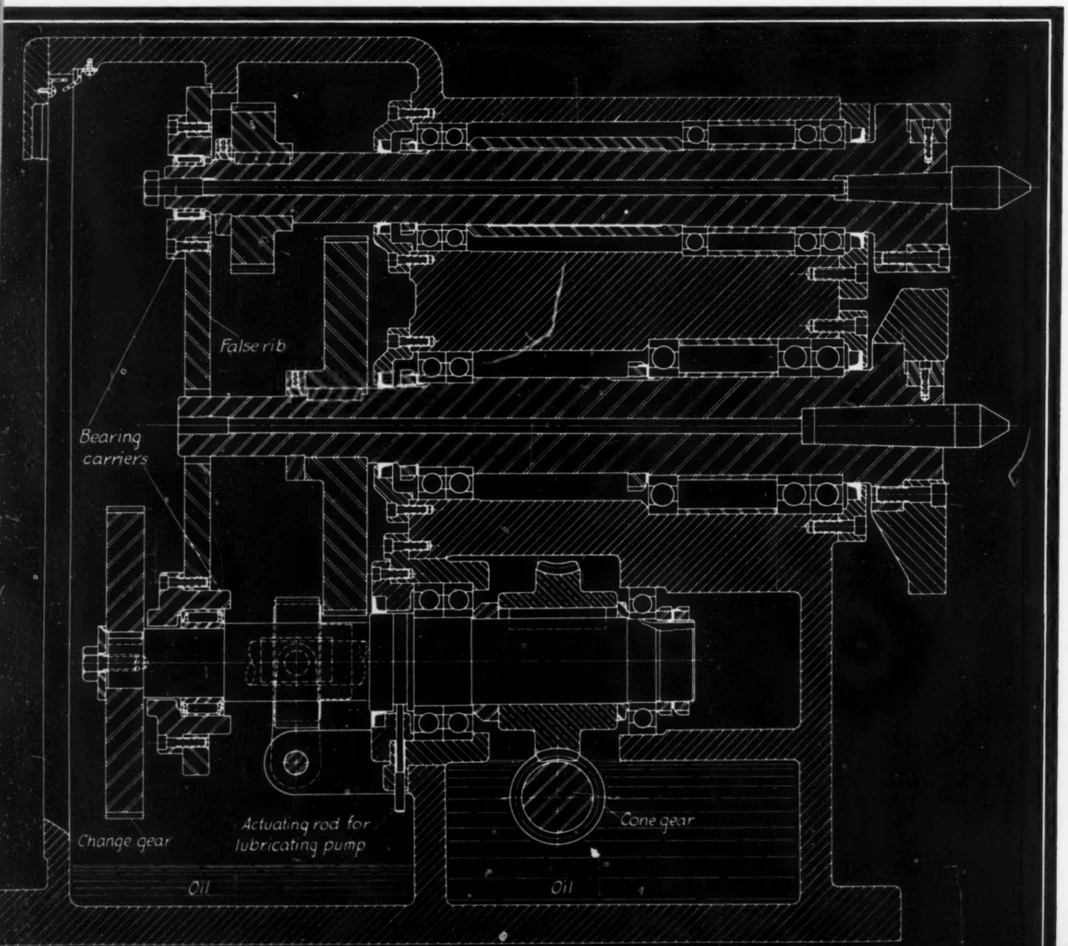


Fig. 3—Change gears for headstock are indicated at H and I. False rib for bench assembly is indicated by A, and lubricating pump by J. Angles mounted on door prevent any oil from escaping through it

Fig. 2—Developed cross-sectional view of headstock showing two-spindle drive



The position of the inner bearing, nearer the center of the spindle, assures better ability of the shaft to resist bending. This is of special value when an attachment for shaving internal gears is used, since with this attachment, an outer support for the gear to be shaved is seldom provided and the tailstock is never used. The bearing spacers between the outer tandem bearings and the near-center bearing are of equal length, to provide identically the same preloading as is built in initially.

Bench assembly of the spindles, combined with the complete enclosure of each spindle in its hole in the housing makes it possible to furnish separate lubrication for their bearings from that provided for the driving mechanism and other parts. The bearings are pressure-lubricated through separate fittings. Enough lubricant is

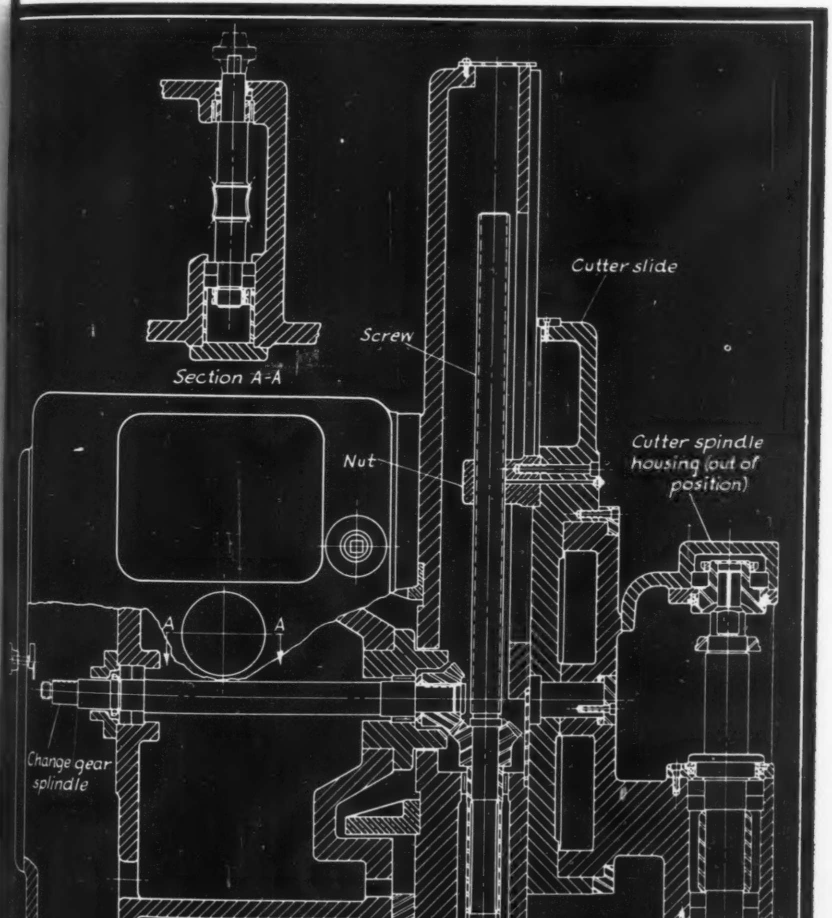
retained inside the seals to last for 6 months, at which time additional lubricants may be forced into the fittings.

In addition, the design of the driving mechanism is noteworthy. Through the use of a false rib or plate shown in *Figs.* 2 and 3, the drive gearing becomes a seperate unit from the spindle assembly. This rib not only facilitates the bench assembly of the bearings on the spindles, but also places the driving stresses outside of their main support bearings. By having the drive gear on the large shaft mounted close to the inner support bearing, no outrigger bearing is used, but one is provided for the small shaft in the false rib, due to the smaller size. It may be mentioned that the cone-drive gear shaft shown in *Fig.* 2 is also bench assembled, as is the pinion shaft.

A double-spindle headstock and mating dual tailstock were desired for the following reasons:

1. To reduce overall size by shortening the cutter column slide travel
2. To give greater selection of spindle speeds from smallest to largest work
3. To provide a more rugged spindle for mounting large

Fig. 4—Drive for cutter spindle slide is through bevel gears and screw with a nut on the cutter slide. Section A-A shows drive to gear 1 seen in Fig. 5



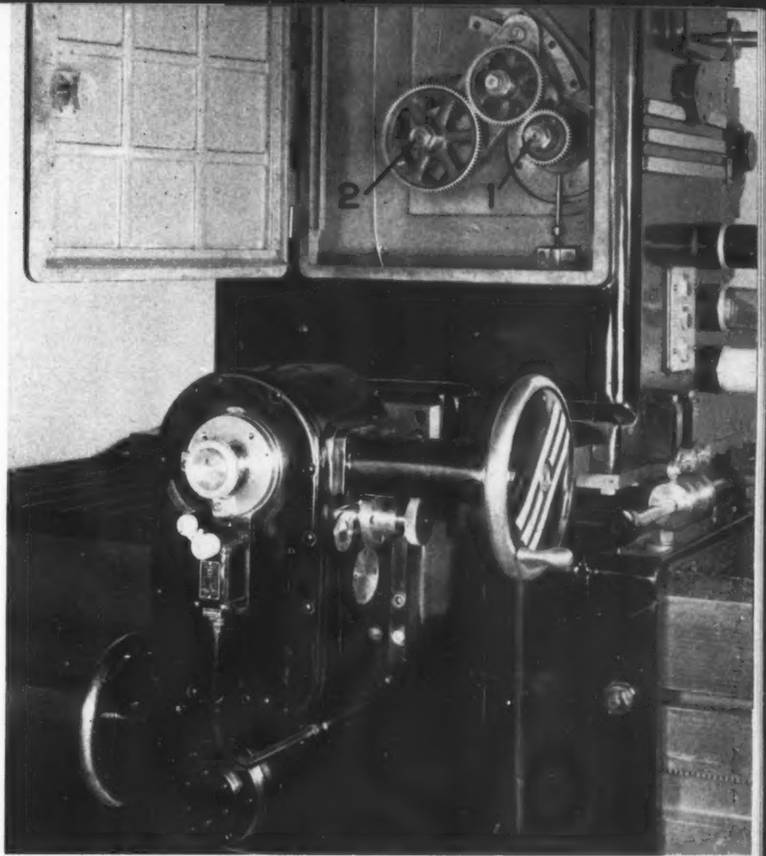


Fig. 5—Cutter-spindle carriage and change gear drive. Drive unit is bench assembled. Gear 2 is driven by gear 1 and drives spindle slide through gears, screw and nut

work than could be permitted otherwise, due to interference encountered with small work.

With the two-spindle headstock and only one main drive unit and single set of eight pick-off change gears, 12 speeds ranging from 16 to 240 revolutions per minute for the two spindles is provided with the change gears regularly supplied with the machine. Because of the ability to use a large gear on the larger of the two spindles (for the slower speeds) and to shift the drive easily from one spindle to the other, suitable shaving speeds can be obtained.

In assembling the headstock mechanism, the spindle and gear shafts are first installed, seals and caps attached, large gear mounted and the false rib placed in position. The gear shaft assembly includes an actuating cam and rod for a lubrication pump. The false rib or plate is fastened to the housing casting by means of screws and dowel pins. Bearing carriers, *Fig.* 2, are next assembled to the plate, followed by a shaft carrying the spindle-drive slider gear. Change gears (*Fig.* 3) may now be mounted. To complete the drive, driveshaft is connected by a V-belt to the driving motor in the base of the machine.

The lubricating pump, *Fig.* 3, which is actuated by the rod shown in *Fig.* 2, is connected through metering valves to various bearings (exclusive of those on the spindles) and to all gears. To effect a leak-proof joint at the door of the housing in *Fig.* 3,

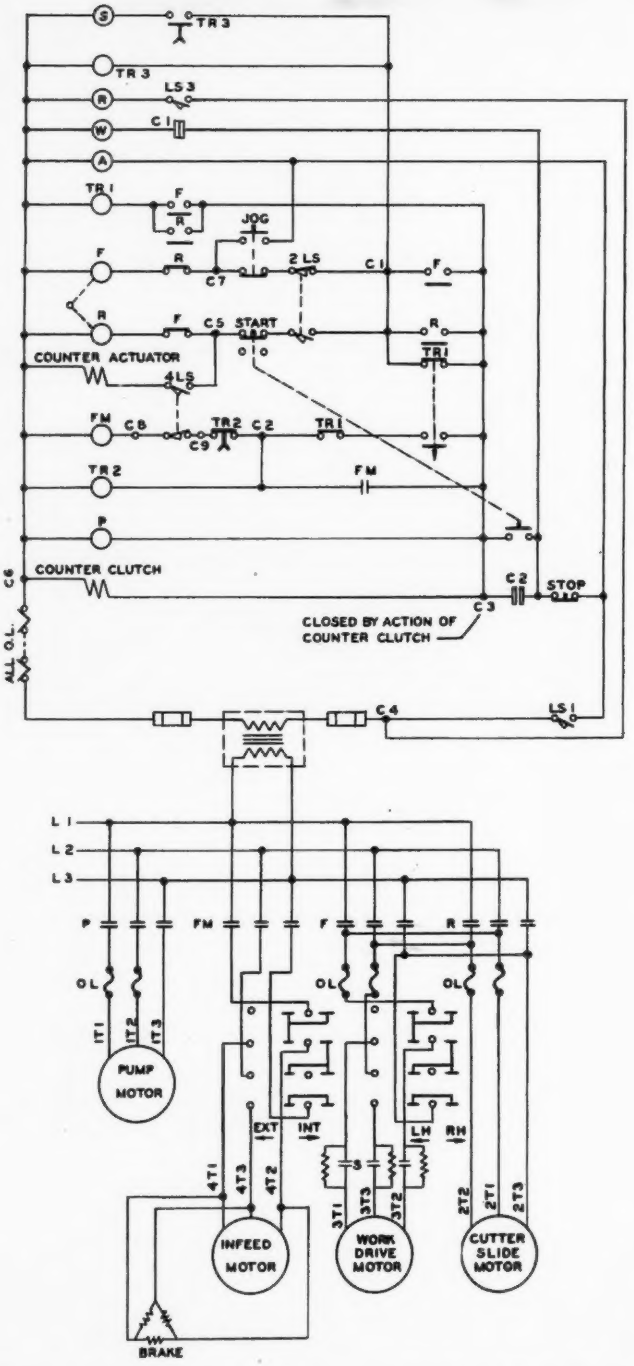


Fig. 6—Schematic wiring diagram indicating interlocking controls for the various preset motions

an angle iron fastened to the inside of the door projects into the housing, between the latter and a steel strip attached to machined surfaces just inside the opening.

The cutter spindle is mounted on preloaded antifriction bearings and is similar in design to the work spindles in that it also incorporates the bench-assembly feature. *Figs.* 4 and 5 illustrate some of the back column features. The first unit of the slide drive is through a cone gear (inset *Fig.* 4) to shaft 1 shown in *Fig.* 5. The mounting arrangement for this is substantially the same as for the work spindles, namely, bench assembly. The change gears as shown drive a bevel gear meshing with a mating gear which in turn drives the cutter slide through a screw.

The cutter slide ways may be positioned for operating the slide either parallel or transversely to the headstock spindles. To form a circular T-slot on the column for rotating the cutter head to desired crossed-axis position with the gear to be shaved, two steel rings are used. These are lathe turned and then attached to the column, since it is difficult to turn a slot of this kind directly in such a heavy and odd-shaped piece as the housing.

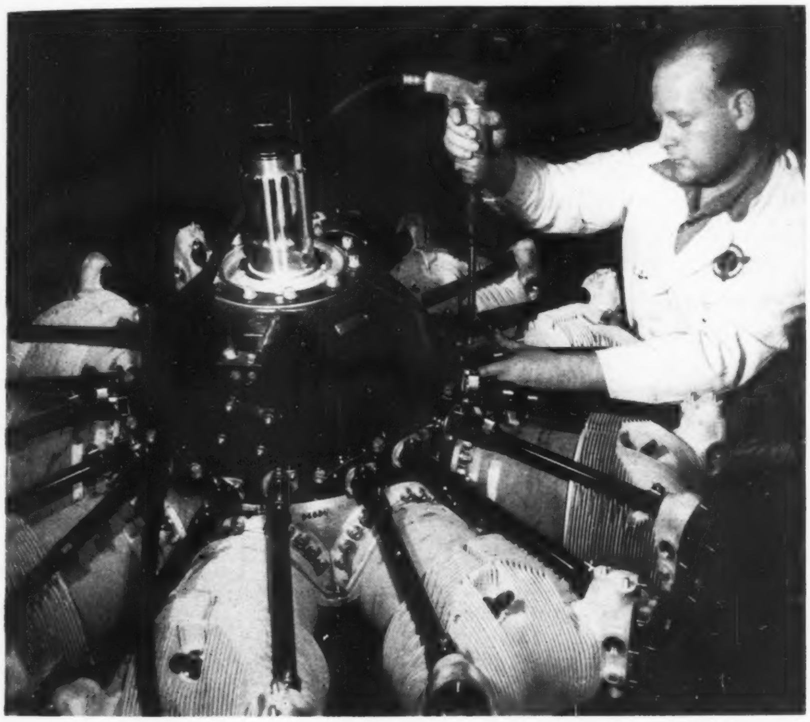
Complete electrical control for the machine was selected for purposes of simplicity and to provide utmost flexibility. This method of control also has the advantage that several subassemblies that are not mechanically connected can be electrically interconnected, often eliminating such mechanical connections as links, shafts, cams, plungers, and similar parts. Also, with electrical control the entire cycle of a machine can be changed by changing a few connections.

A schematic diagram for the control circuit is shown in *Fig.* 6. In each large assembly unit where controls are used, there is an opening, covered by a door, inside of which marked terminal blocks are provided, with wiring to each electrical unit. This practice not only enhances the appearance of the machine, but simplifies construction as well as facilitates maintenance.

As shown in Fig. 5 limit switches, signal lights and control buttons are mounted without the use of conduits. The lights are of various colors and indicate conditions existing during the set-up and working cycles. The control system also includes full overload and undervoltage protection by an interlock and thermal overload switches.

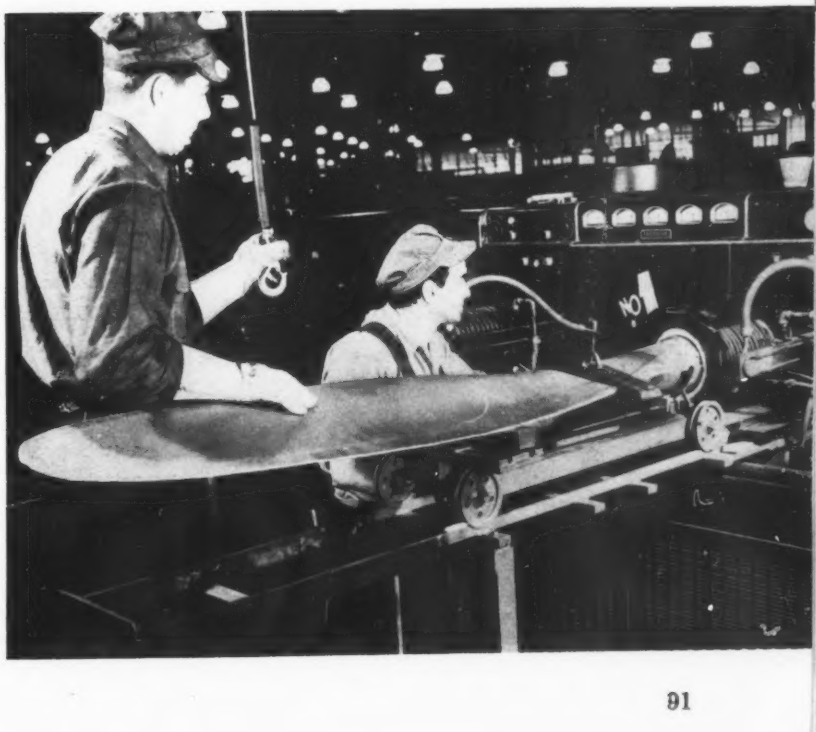
GUN-SHAPED tool is heated electrically for exploding rivets in hard to reach places in planes. Principal parts of the "gun" are modifications of an electric range heating unit and electric iron thermostat. The heater, sealed in tube-shaped metal jacket is embedded in the cast-iron barrel while the thermostat is placed in the cord circuit. Accurate heat control of this Westinghouse unit assures that maximum strength of rivet is developed by obtaining full force of explosion.

Scanning the field for IDEAS

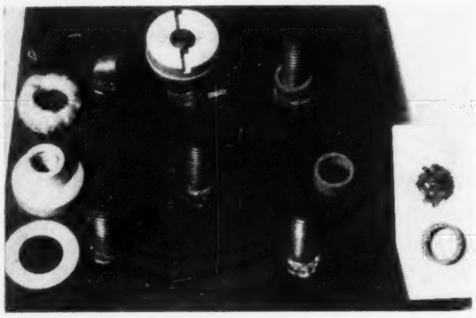


Forging operations utilizing induction heating have greatly reduced the time required by heating in gas furnaces. In the illustration below a propeller shank, heated by the Tocco process, reduces the heating time to one fifth. The hollow shank, 4⅝ inches in diameter, is swaged in this operation to a perfect circumference. Heat generated by internal molecular friction caused by the rapidly reversing induced current raises the temperature in the section to 1700 degrees Fahr. in 150 seconds. This rapid method of

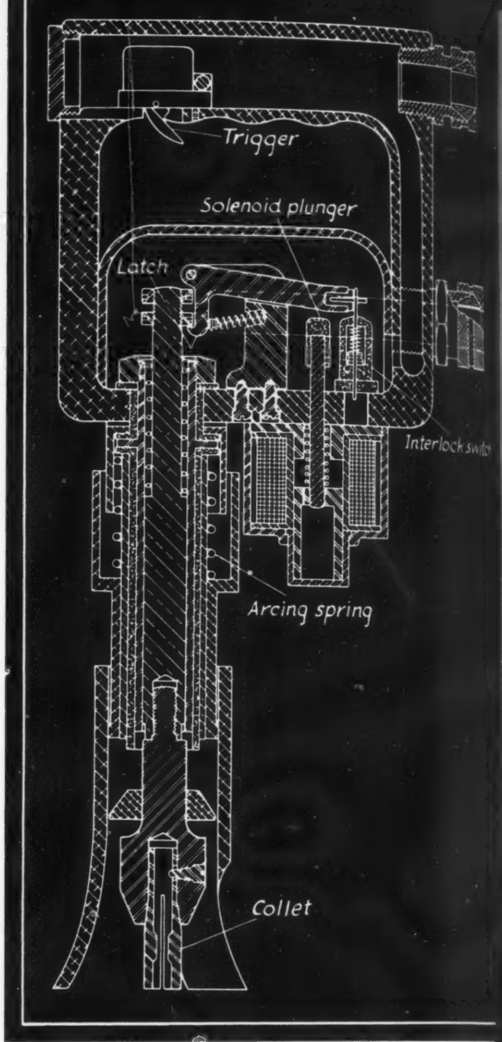
Plastics replace two sheet aluminum parts in the Wright Cyclone engine above, effecting a savings of many thousand pounds of the vital metal monthly, giving twice the service life of the parts involved and providing reductions in engine weight, manufacturing time and costs. The two parts—baffles or air deflectors and push rod housing—are in quantity production and other manufacturers are expected to adopt them as standard. Made in one instead of five operations the parts are fabric impregnated with phenolic resin and are formed in molds and cured under heat and pressure. The baffles deflect the air stream over the entire finned surface of the cylinders, providing rear bank cylinders with the same cooling as the front. The push rod housings, one-inch tubes about twelve inches long, protect the push rods and act as a return channel for oil carried to the entire valve mechanism.



heating reduces the hazards of scaling to a minimum. Heating for upsetting operations is similarly performed.



To eliminate personal judgment in stud welding and to facilitate other operations involving end welding of steel sections, the tool shown at right embodies automatic control. For certain assemblies it is possible to weld studs after parts to be assembled are in place, obviating layout time or special fixtures. Shown in the photograph above are several studs welded to a steel plate.

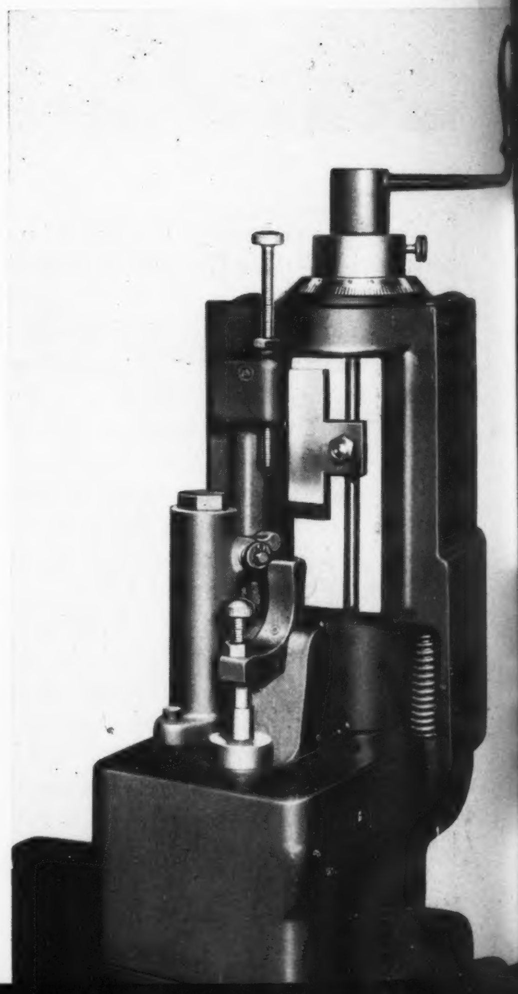


Operation of the gun, developed by the Hollup Corp., involves cocking by pushing a stud to be welded into a collet and against the action of a forging spring until it is compressed sufficiently to close a latch. Spot where stud is to be welded is prepared by placing a ferrule in position with a measured amount of arc-inducing material. The gun is then held over this spot while a trigger is pressed to initiate the automatic welding cycle.

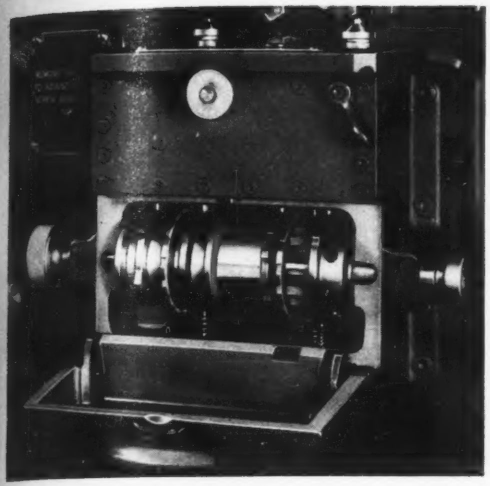
This trigger energizes the control circuit which allows the welding current to flow for a predetermined length of time, sufficient to form a pool of molten metal in the ferrule. At the end of the cycle, a solenoid is energized to open the latch, forcing the stud into the pool of molten metal. When the latch is opened, an interlock switch interrupts the welding current. This action also cuts out the trigger circuit so that, even if the operator continues to hold the trigger, no welding current can flow when the gun is removed from the stud. The collet is arranged so that it releases the stud upon withdrawal of the gun. The control cabinet utilizes a contactor for the welding current, an adjustable timing relay for limiting the welding current, an auxiliary relay for control circuit and a current relay to prevent false operation.

Gun circuits cannot be operated unless the gun is first cocked. The current relay will not operate when the main contactor is closed by operating the gun operating switch unless the stud is actually in contact with arc-inducing material and unless the material is in actual contact with the steel plate, thereby completing the welding circuit. The timing relay will not operate unless the current relay first operates.

Hydraulically actuated mechanism automatically controls vertical movement of the spindle carrier, at right, for a Cincinnati milling machine. Synchronized with the table traverse motion it provides for a great variety of milling cuts such as are encountered when a projection on part or fixture prohibits the work from being advanced directly into the cutter or where the cutter must be raised and lowered to jump an obstruction. Many parts for machine guns, automatic rifles and side arms require cuts of this type.



Mechanism consists of a hydraulic cylinder and valving mounted in a bracket on top of the machine column. Approach

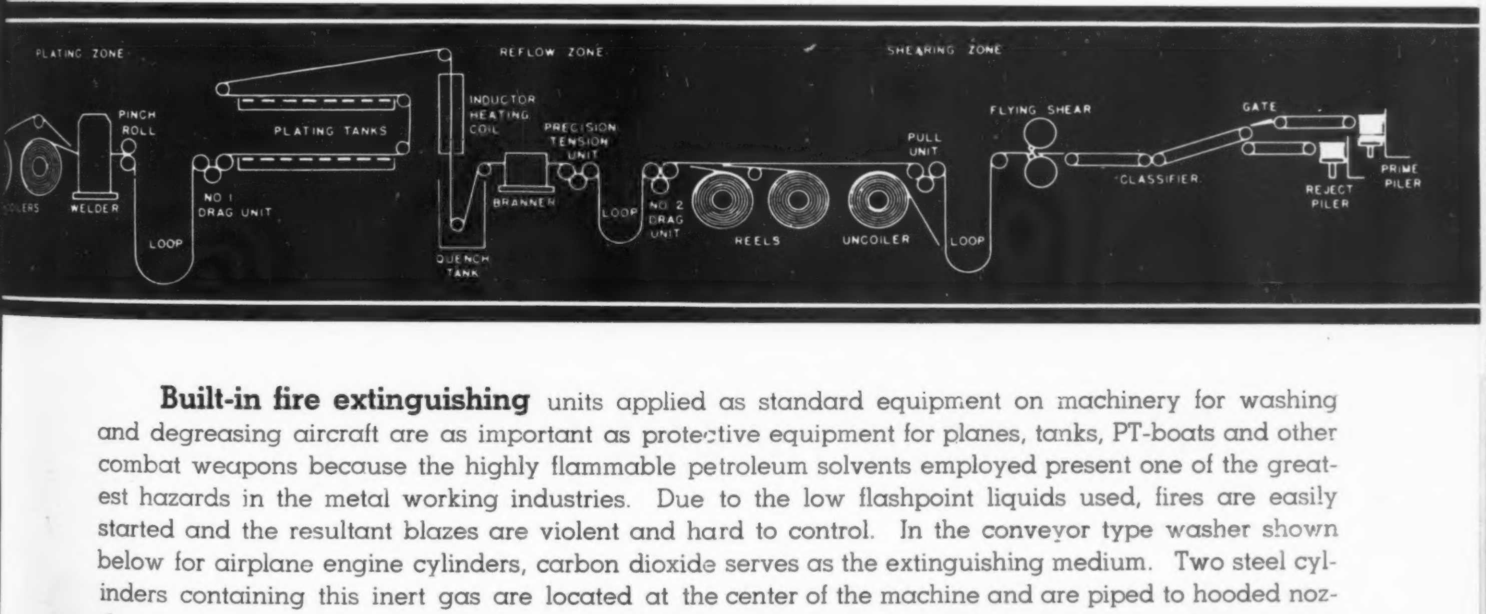


of the cutter to the work may be set at rate desired. Return from work is at a fixed rapid rate. The synchronized motions are obtained by cycle selectors as shown above consisting of a simple cam shaft assembly. These selectors, easily replaced to vary the cycle, merely select the motions while dogs on the spindle carrier and table govern the length of cut.

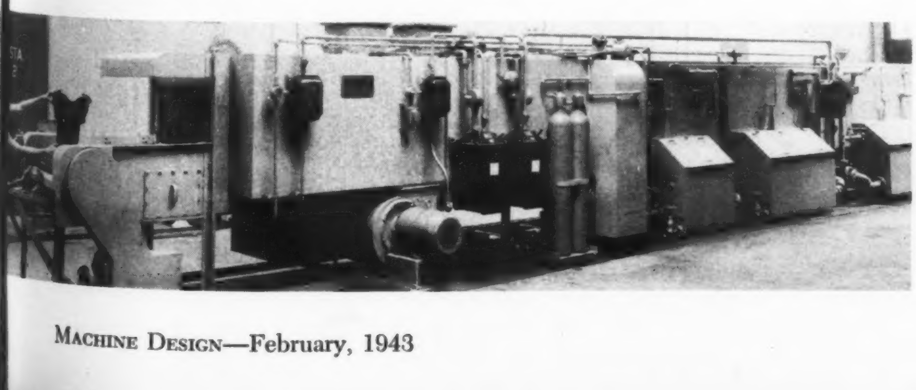
High frequency fusing of tin which has been electrolytically deposited on steel sheet increases the corrosion protection of the coating. Heating the granular deposit to the melting point in this way fuses it to a smooth even coating. In addition to increasing protection, the smooth surface aids in handling sheets in high speed canmaking machinery providing better operation of the suction-cup feeding mechanism. Shown in the sketch below is a continuous system developed by Westinghouse for providing either strip or sheet, electroplated and fused by this new method. By combining the systems in this way handling is reduced and thus a better product is obtained with less spoilage.

Frequency of 200,000 cycles a second is considered the most practical for tinplate of the order of .008 to .011-inch. An inductor heater coil, rectangular in form and wound as close to the strip as possible induces a flow of current across the strip. Heat is generated due to the flowing current and to the resistance of the strip. Carefully controlled temperature of 450 degrees Fahr. heats the tin to the melting point and causes it to flow into a smooth surface. A water quenching tank hardens the tin, reducing the temperature below 100 degrees.

Power is supplied by vacuum tube oscillators. Conventional current is rectified to direct current and fed to oscillator tubes where it is converted to 200,000 cycles. Rotating machinery would be limited to less than 15,000 cycles. One plant is installing oscillator units with 72 times the power of the most powerful radio broadcasting station in the country.



Built-in fire extinguishing units applied as standard equipment on machinery for washing and degreasing aircraft are as important as protective equipment for planes, tanks, PT-boats and other combat weapons because the highly flammable petroleum solvents employed present one of the greatest hazards in the metal working industries. Due to the low flashpoint liquids used, fires are easily started and the resultant blazes are violent and hard to control. In the conveyor type washer shown below for airplane engine cylinders, carbon dioxide serves as the extinguishing medium. Two steel cylinders containing this inert gas are located at the center of the machine and are piped to hooded nozzles at points where fires might start. A Walter Kidde "local application" system, it utilizes a rate-of-temperature-rise detector. This reacts to a sudden rise in temperature by expanding the air in the system sufficiently to open the valves and discharge carbon dioxide. Outside manual auxiliary valves are also conveniently located remote from possible danger as an additional safety feature.



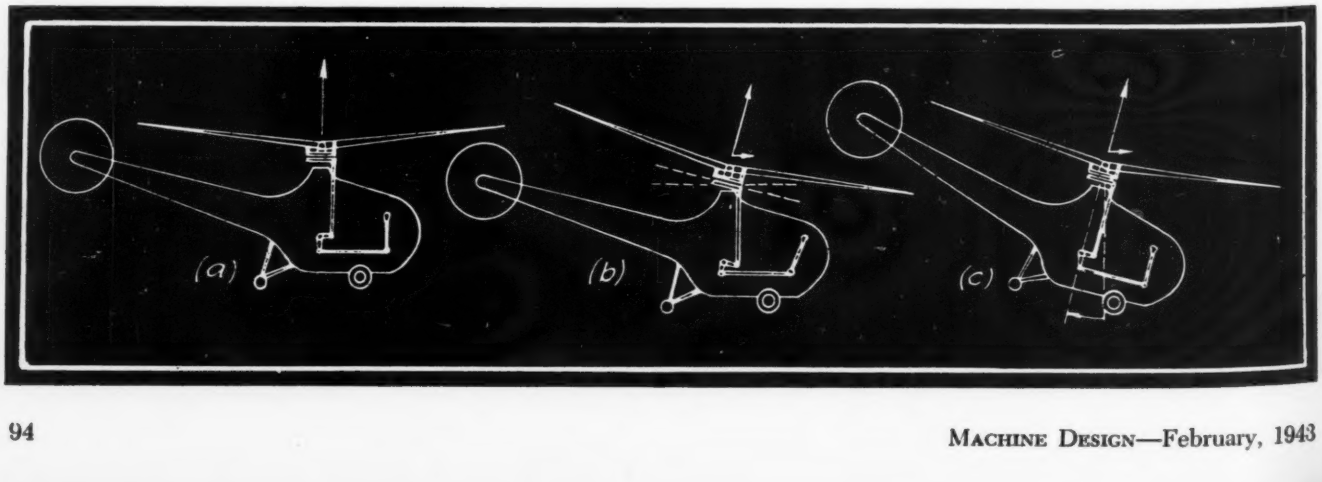
Helicopter Blazes Trail For New Flying Era

DIRECT-LIFT aircraft or helicopters which need no horizontal run for take-off and landing are likely to play an important part in the present conflict. Ability to dodge in and out among trees, to hover indefinitely over one spot, to fly backward and sideways as well as forward, and to perform other remarkable feats give such craft a military value limited only by the imagination.

Potential uses in time of peace, particularly for private operation and short-haul services, are so extensive that it is believed that within ten years after the war the manufacture, sale and upkeep of helicopters will be a billion-

Fig. 1—Top—Its designer flies the VS-300 up to a man unable to move from where he is standing, picks up a load, and backs off

Fig. 2—Below—Diagrams show in succession hovering flight, tilting of the rotor head due to pushing the stick forward, and inclination of the fuselage in forward flight



dollar industry.

While new developments which must for the present remain secret for military reasons will undoubtedly produce further improvements in handling, it is felt that the basic problems of direct-lift flight, including control and stability, have been successfully solved in the VS-300 helicopter, designed by Igor I. Sikorsky, the noted Russian-born aircraft designer, and built by Vought-Sikorsky Aircraft. A discussion of the principles of helicopter design with special reference to the VS-300 should therefore be of interest to engineers.

How Direct Lift Is Obtained

Because propeller or rotor thrust in a helicopter must exceed the weight of the ship in order to lift it straight off the ground, it is natural to question how this is possible without a tremendous horsepower per pound ratio, inasmuch as even our most powerful fighter planes can climb only at a relatively flat angle. The explanation lies in the fact that the rotor blades are simply wings in which the relative air movement necessary to produce lift is the result of rotation instead of forward flight. The engine merely has to overcome the drag of these rotating wings, which is no more than that of a conventional wing. In the VS-300, which can lift two men, a 90-horsepower engine is sufficient for all normal conditions of flight.

Design of the main rotor owes much to the successful development of the autogyro with its articulated blades, rotor balance, rotor control, etc. The fundamental difference is that in the helicopter the rotor is positively driven by the engine under all normal conditions. The three-bladed main rotor has a diameter of 28 feet and normally turns at 280 revolutions per minute when in flight, power being transmitted through a reduction gear. An auxiliary two-bladed propeller at the tail, *Fig.* 1, is provided for torque compensation and directional control, as will be explained later. This propeller, which is 92 inches in diameter, rotates in a vertical plane and is driven at about five times the main rotor speed through multiple V-belts and bevel gears.

Angle of incidence of the main rotor blades is controllable within a range of from 2 to 13 degrees, providing control of the lifting force and therefore of the vertical movement of the ship. A control lever in the cockpit at the pilot's left hand actuates the pitch control, the throttle being interconnected so that increasing power is furnished to the rotor as the pitch increases without the need of manual adjustment of the throttle.

Prior to taking off, the pilot brings the rotor up to speed with the blades at low angle of incidence, then increases the incidence until the machine begins to rise. Rate of ascent is at all times under perfect control and the machine may be stopped in mid-air whenever it has attained

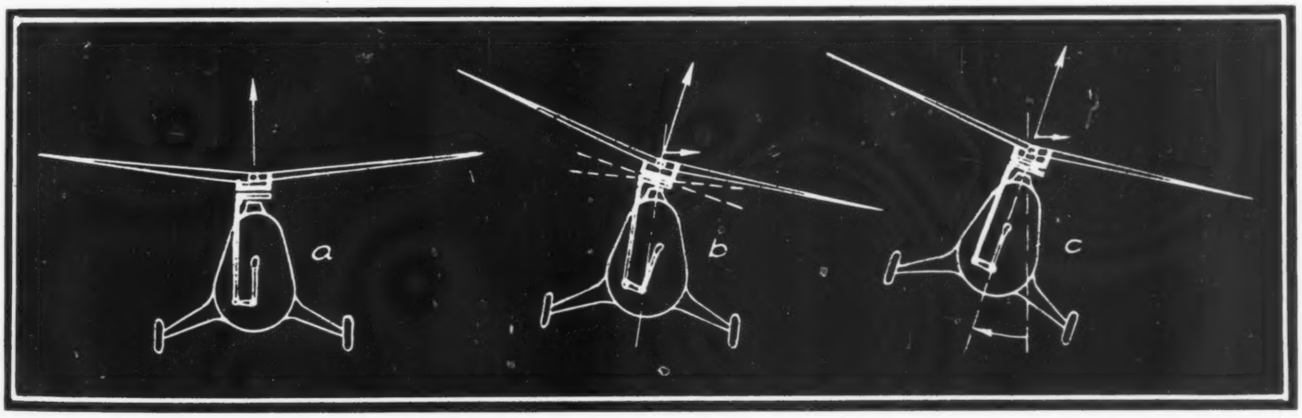


Fig. 3 — Above — Successive stages from hovering to sidewise motion. Similar sequence of attitudes of the ship accompanies acceleration in any direction

Fig. 4—Right—Precision control is demonstrated by changing a tire while the helicopter hovers in flight

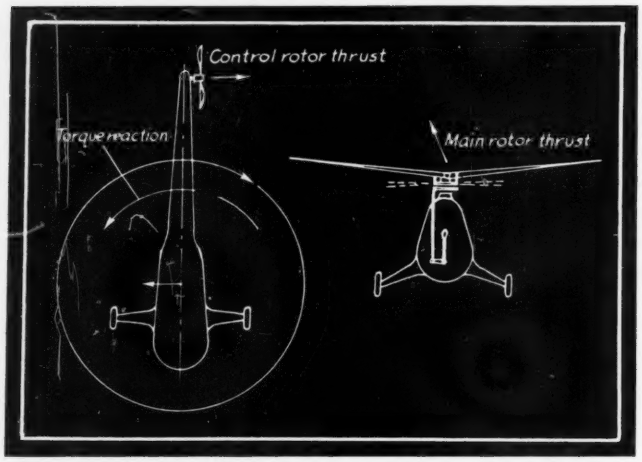


Fig. 5—Moment created by control rotor counteracts torque reaction from main rotor. Small sidewise inclination of main rotor produces balance force

sufficient altitude for forward flight. In demonstration tests it has hovered for more than an hour and a half over one spot.

To attain forward motion the pilot pushes forward a control stick held in his right hand. Effect of this movement is to change the angle of incidence of the rotor blades progressively throughout the cycle of rotation. As each blade passes over the longitudinal axis to the rear its angle of incidence becomes maximum, the minimum value occurring at 180 degrees from this position. Thus the lift is increased on the blade at the rear and decreased on the one at the front, exerting a moment which tilts the rotor head forward. This is shown in *Fig. 2b,* from which it is evident that the horizontal component of the lift vector will act to propel the ship forward. Another effect of the tilting is to create a moment which inclines the ship so as to bring it once more into normal relation with the rotor, as shown in *Fig. 2c,* the control stick returning to neutral position. With the ship thus inclined the horizontal vector component accelerates the ship until balanced by the drag due to forward motion. Because the ratio of drag to lift is relatively small, the tilting of the ship in forward flight amounts to only a few degrees at unifom speed.

Fig. 6—The VS-300 is about to settle in a water inlet just large enough to accommodate the sweep of the rotor blades

While forward speeds up to 80 miles per hour have been attained with the present model, later designs will provide for speeds up to 140.

The principle by which forward motion is attained works equally well when it is desired to go backward or sideways. In such cases the control stick is moved in the intended direction of motion, thus changing the blade incidence to minimum in that direction and maximum in the opposite direction. Tilting of the rotor disk and then of the ship occur exactly as in forward flight. The action is shown for sidewise motion in *Fig.* 3.

Because take-off and landing normally occur without any run, a ship equipped with inflated rubber floats, as in *Fig.* 1, is completely amphibious and can even land on mud or marsh land. For land operation exclusively, conventional wheel-type landing gear as in *Fig.* 4 permits rolling on the ground into and out of the hangar. It also permits landing with a short run as is desirable in the event of engine failure. An overrunning clutch in the drive mechanism allows the rotor to continue spinning, and the machine then performs as an autogyro. The best technique for power-off landing requires that the craft glide down with 20 to 40 miles per hour air speed, the pilot "flaring out" a few feet off the ground so that the impact is reduced to normal aircraft proportions. This usually will involve a short landing run of 10 to 15 feet. If the pilot cares to, however, he can settle vertically but he will sacrifice the advantage of the flare out and will land with considerable impact.

Problems of Control Successfully Met

Directional control and stability were among the most difficult problems encountered in early helicopters. Torque reaction from the rotor tends to spin the craft in the direction opposite to that of the rotor, and to overcome this tendency a control rotor is provided at the tail. As shown in *Fig.* 5 the moment of the lateral thrust developed by the control rotor counteracts the torque reaction of the main rotor. The lateral thrust is itself balanced by an equal and opposite force at the main rotor furnished by giving the rotor disk a slight inclination to one side as shown in the front view, *Fig.* 5. Pitch of the control rotor can be varied at the will of the pilot by means of rudder pedals, a change resulting in unbalance between torque reaction and control torque which rotates the ship into any direction desired.

Longitudinal and lateral pendular stability are inherent in the design because of the high location of the lifting force at the rotor in relation to the center of gravity.

On test flights the VS-300 was flown with equal ease in any direction and could rise and descend at any angle with the ground. Precision control was demonstrated by such feats as are illustrated in *Figs.* 1 and 4, and by the ability to settle in a water inlet just large enough to permit swinging the rotor blades, *Fig.* 6. On the water the aircraft was found to be more easily handled than any other surface vessel and in the air it could be stopped in a shorter distance than an automobile traveling at the same speed. Because high speed is not essential to its operation fog is not the hazard to a helicopter that it is to a conventional airplane, and built-up areas, trees, mountains, etc., do not impede its handling.

Fig. 1—Difficult forging problems are worked out in engineering conferences. Wax models aid in the design of intricate parts

Applying Forgings in Design

By Colin Carmichael

Part I—Drop Forgings

WITH the national requirement for forgings for war machines beyond the capacity of the industry, it is imperative that the most effective use of production facilities be realized. Of equal importance is the fullest utilization of forging techniques to save machining operations, thus relieving the burden on machine tools. A proper understanding of the principles of forging design will enable the designer to utilize those features which contribute to economy in production, sound parts, development of maximum strength with minimum weight and other desired qualities.

This article, the first of two, summarizes the basic factors affecting the design of hammer and drop forgings. The second will cover, in like manner, press and upset forgings.

Hammer forgings, also known as smith or flat die forgings—produced by turning a billet or bar while it is being shaped under a steam or air hammer—are employed for parts of simple contour such as shafts, bars, large crankshafts, rings, flats, axles, and die blocks. Remarkably accurate smith forgings can be developed using flat dies or inexpensive tooling. Simple small parts ar similarly produced, blacksmith fashion, with a hand hammer or with a mechanically operated helve hammer.

Drop forgings, or die forgings, produced by the forcing of the heated metal bar into the two cavities of a die, embrace a wide range of applications including cams, levers, gear blanks, connecting rods, crankshafts, and all types of highly stressed parts ranging in size from a fraction of a pound to 800 pounds per piece.

Hammer and drop forgings depend on impact to cause deformation of the forging blank, while press and upset forgings use a gradually applied pressure or squeezing

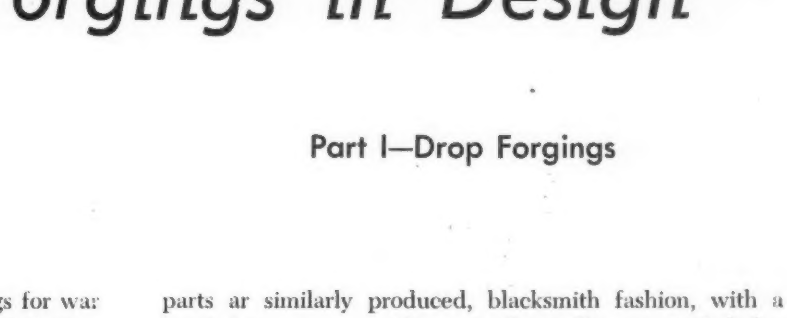


Fig. 2—Power axle for an industrial truck is a heat-treated drop forging.

force. The effect on grain refinement of the metal, with drop forging, depends generally on the amount of hammering. Grain flow in both hammered and pressed forgings is controlled by proper die design.

Because the design of a forged part is affected by forging technique, the most satisfactory compromise between part design and die design for intricate parts is attained through engineering conferences, *Fig.* 1. Use of preliminary models aids materially in arriving at the best all-round solution. When the part is relatively simple, the designer cannot go far wrong if he is able to visualize the forging process and pays careful attention to certain factors, the most important of which are discussed in the following.

To allow the piece to separate easily from dies, draft is necessary on all surfaces which are nominally parallel to the line of action of the hammer. Hot plastic metal tends to stick to the dies, the inevitable minute surface roughness of which tends to aggravate the condition. Draft angles should always be kept as small as possible, because they almost invariably call for machining operations to remove the excess metal. Modern steam drop hammers will produce forgings, like automobile crankshafts, with 1½ degrees of draft and board drop hammers will produce commercial work with 3½ degrees of draft. However, in both these cases draft angles may have to be increased up to a maximum of 10 degrees to accommodate older style forging equipment, especially for intricate forgings.

If draft is not indicated on the drawing, the forging supplier will add draft, as shown on the forging at the left of *Fig.* 2. In the example illustrated the outside surface of the axle was subsequently machined parallel as shown at the right of *Fig.* 2. Frequently it is possible to avoid adding metal for draft by decreasing the metal thickness toward the outer end of the part, and if this can be done it should be indicated. Radial draft is provided on the ends of cylinders and the like which lie with their axes in the plane of separation of the top and bottom dies. The end instead of being flat is a portion of a sphere, usually drawn with a radius equal to twice the cylinder diameter but not dimensioned.

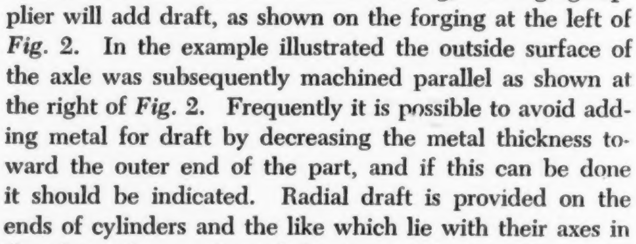


Fig. 3—Drop forged steering head for army motor cycle combines light weight with high resistance to shock. Forging accuracy is of particular importance

Closely associated with draft is the selection of the parting line, or line of separation of the top and bottom dies. All dimensions of the part parallel to the plane of the parting line are maximum in this plane. Draft therefore begins at the parting line. While a single plane parting is desirable from the standpoint of simplicity, it is by no means essential and frequently changes are made in the plane of the mating faces. Such dies are called locked dies and if more than one change of plane is made it is referred to as a compound lock. Sometimes parts are cocked in the dies so that a particular surface may have draft in the die yet be perpendicular to the axis of the piece.

Fillets as large as possible are necessary to assist flow of hot metal, to promote economical manufacture, and to prevent cracks developing in the part. Large corner radii on the piece, corresponding to fillets in the dies, are likewise essential to prevent cracks developing in the dies.

Avoid Deep Depressions in Parts

Deep pockets and narrow recesses in the part correspond to weak protrusions in the die which tend to overheat and fail under the pressure of hot metal during forging. A good rule for conventional forgings is to limit the depth of a depression or forged hole to two-thirds of the least width.

Projections on the piece such as bosses (length of projection less than the diameter) or stems (length of projection greater than the diameter) can either project vertically into the die cavity or lie parallel to the parting line. An example of the latter practice is apparent in *Fig.* 2, where the parting line shows clearly along the sides of the projecting stems.

Thin ribs or webs generally tend to increase forging difficulties, especially in alloy or stainless steels. Thicknesses not less than 3/32-inch to ⅛-inch or more are preferred.

Tolerances and machining allowances should be designed so that lowest overall cost of the finished part results. Close forging tolerance does not necessarily involve a reduction in machining cost, if production time is lost in positioning. A part such as the steering head for an army motorcycle illustrated in *Fig.* 3 must be made to extremely close tolerances because of the small thickness of metal remaining after the piece has been bored out to receive the tubular members.

Die wear is an important factor to consider in selecting tolerances. As each piece is formed the impression in the die becomes slightly worn so that successive forgings increase in size. When this increase reaches the upper tolerance limit remachining of the die impression is necessary, the die being initially machined to dimensions corresponding to the lower tolerance limits on the piece. By specifying largest possible tolerances more parts can be produced without resinking the dies, thus reducing cost.

Regular standard tolerances adopted by the Drop Forging association are classified as "commercial" for general forging practice and "close" where high accuracy is desired, involving additional expense. Thickness tolerances apply to dimensions perpendicular to the parting plane and are standardized according to the net weight of the piece.

Close tolerances are half the commercial tolerances, thus require resinking approximately twice as often. Width and length tolerances, for dimensions parallel to the parting plane, are affected by shrinkage, die wear, mismatching and trimming. Shrinkage and die wear tolerances apply only to dimensions wholly within one half of the piece, that is, they do not include dimensions which cross the parting line. Shrinkage tolerances are based on the dimensions to which they apply, and are plus or minus .003-inch per inch for commercial and half this value for close tolerances. Die wear tolerances are based on the net weight of the piece as in the case of thickness. Mismatching is the relative displacement of upper and lower dies from their correct position, and mismatching tolerances are therefore independent of and in addition to any other tolerances. They are based on the net weight of the part. Draft angle commercial limits are 0 to 10 degrees for outside surfaces and 0 to 13 degrees for inside holes, the corresponding close limits being 0 to 8 degrees in each case. These can be materially reduced using modern equipment. Trimmed size tolerance is determined by the sum of the draft angle tolerances and the shrinkage and die wear tolerances. Fillet and corner radii in excess of certain standard values based on net weight of the part are considered special.

Trimming the flash from the forged piece is an essential operation in the production of drop forgings and is generally done on an adjacent press using special trimming dies. In normal trimming the part is trimmed to the dimensions determined by the intersection of the draft surfaces and the parting line of the forging dies. Close trimming may be used to give increased accuracy to certain dimensions by shearing off a small portion of the forged body. Before specifying a close trim the designer should consult with the forging engineer, as in some cases it may cause difficulties.

Fig. 4—Typical of aircraft drop forgings is this main frame cross tie

Supplementing the essential processes of forging and trimming, several refining operations can be performed which improve the quality of the part. An extra degree of accuracy and finish may be secured by subsequent coining or sizing on a special press or hammer and often done cold. With coining, tolerances on certain dimensions are commonly held to about one-half the close tolerance limits. With this accuracy, some machining operations may often be eliminated. Ironing also imparts smooth surfaces and a high degree of accuracy, and may be used for such modifications as the elimination of draft on certain surfaces. Planishing, which is a combination of ironing and sizing, secures smooth surface and accurate size on cylindrical and spherical surfaces.

When a complex part is required, forging cost may often be reduced and other manufacturing economies developed by fabricating the piece in two or more separate forgings, subsequently joining them by arc or flash welding. Another use of welding is in the production of exhaust valves for diesel engines, the head being forged separately and welded to a stem cut from bar stock. In this case different materials were used for the two parts, to meet the separate conditions of heat resistance and wear resistance respectively. For large pieces produced in small numbers, such as hammer forgings, smith welding the parts together under a hammer at welding temperature is of course a commonly used method.

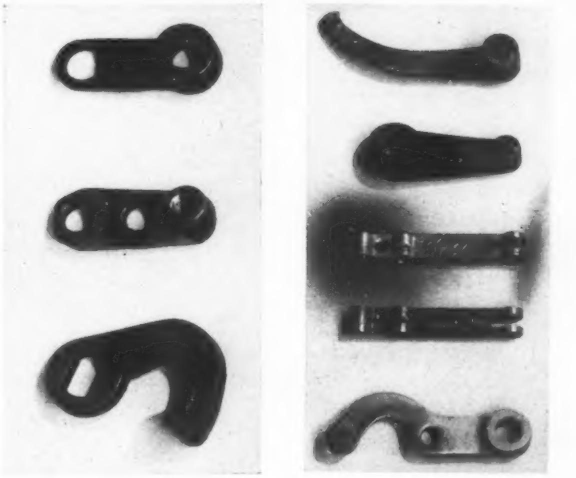


Fig. 5—Control of grain structure at points subject to wear is important in forged typewriter parts

Heat treatment is frequently an essential step in developing the maximum physical properties of the forged piece. Normalizing and annealing relieve internal strains, improve machinability or precede further treatment. Quenching and tempering provide control over strength, hardness, ductility and toughness. Materials such as low carbon steels and certain nonferrous metals which are not susceptible to heat treatment may have their physical properties improved by cold work in the form of shaping or sizing subsequent to hot forging.

Due to the extension of the metal grains in the direction of rolling, billets or bars from which forgings are made have a fibrous structure which gives marked directional properties, chiefly in impact resistance. Advantage is taken of the changes in direction of the fibers due to forging to secure in the finished parts maximum toughness in the direction in which it is most needed. This applies equally to the larger forgings such as the aircraft main frame cross tie, *Fig.* 4, and to small parts used in typewriters and office machines, a group of which is illustrated in *Fig.* 5. Many of these parts weigh less than a pound, yet the directional properties are still present.

In the concluding article fiber direction will be further discussed in relation to upset forgings. Other topics to be covered include press forgings and the commonly used forging materials.

MACHINE DESIGN acknowledges with appreciation the cooperation of the following in supplying material used in the preparation of this article: Chambersburg Engineering Co.; Heppenstall Co.; Kropp Forge Co. (*Fig.* 4); The Steel Improvement & Forge Co. (*Fig.* 1); J. H. Williams & Co.; and the Drop Forging Association (*Figs.* 2, 3 and 5).

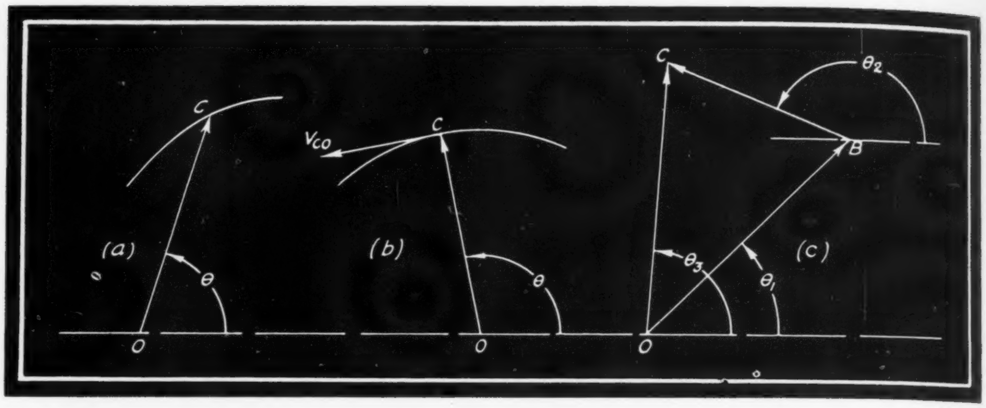


Fig. 1—Vectors denote relative positions and relative velocities of points in a mechanism

How Acceleration Analysis Can Be Improved

Part I

By A. S. Hall and E. S. Ault
Purdue University

TO INSURE trouble-free operation of high-speed mechanisms, correct acceleration analysis of moving parts is of prime importance. While widely used graphical methods based on acceleration polygons or "images" furnish, in general, accurate results with minimum time and effort, for certain types of mechanisms an important factor enters into the analysis which too often

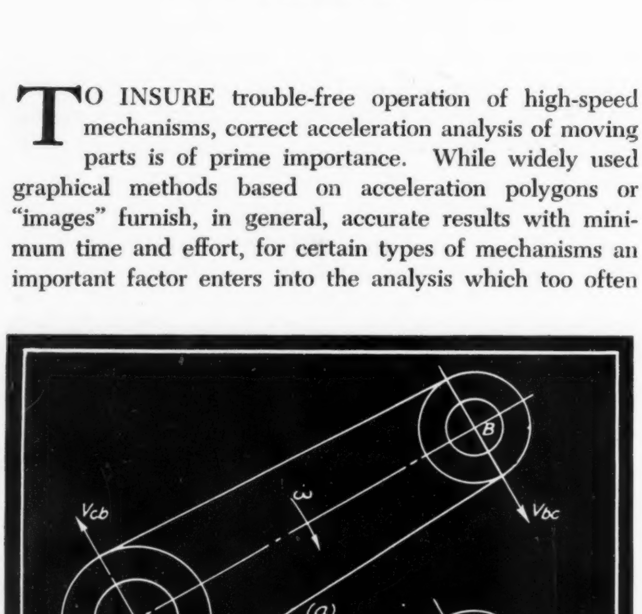


Fig. 2—Relative velocity vectors (a) and acceleration vectors (b) shown for two points on the same link

is neglected. Known as Coriolis' law of acceleration, this effect is usually discussed in textbooks in such a manner that its practical significance is obscured.

Coriolis' law is simply an expression for the relative acceleration between coincident points on different bodies moving independently. For example, in studying a mechanism in which there occurs as part of the linkage a pin on one link working in a slot of another link, it is necessary to know the relation between the acceleration of the center of the pin and the coincident point of the slotted member in order to construct correctly the acceleration polygon for the mechanism. This knowledge is frequently needed to find angular accelerations.

The purpose of this article is to develop briefly the derivation of the relations necessary for the analysis of plane motion in mechanisms, giving particular attention to the derivation and application of Coriolis' law. Interest in this relation is not confined to the study of rigid link mechanisms nor to plane motion. It also enters into an explanation of the forces exerted by a fluid on the vanes of centrifugal pumps and hydraulic couplings.

Distance and Direction Define Relative Motion

Motions of the links of a mechanism are completely determined by the motions of a few key points. The following discussion is based on the concept of the relative motion of two distinct points as a function of the distance between them and of the absolute angular motion of the line connecting them. If at successive time intervals it is possible to state the distance between two points and the angular position of the straight line connecting them, then the motion of one relative to the other is completely determined.

The *position* of one point relative to another is a vector quantity having a magnitude equal to the distance between

the two points and directed from the second toward the first. In *Fig.* 1*a* the position of point C relative to point O is the vector OC having a direction given by the angle θ measured from a fixed reference line. Using the complex notation for a vector quantity the position of C relative to O is $P_{CO} = [OC]e^{i\theta}$, where the symbol $[OC]$ denotes the length of the vector. Both the magnitude of the vector OC and the direction angle θ may be variables. In this expression, e is the base for the natural logarithms and

$$P_{CO} = P_{BO} +\!\!\rightarrow P_{CB}, \text{ or}$$

$$[OC]e^{i\theta_3} = [OB]e^{i\theta_1} + [BC]e^{i\theta_2} \qquad (1)$$

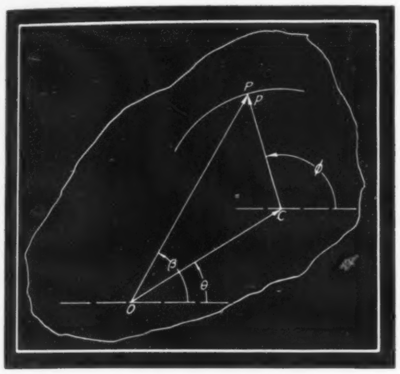


Fig. 3—Points O, C, and P are on the same body, point p being on another link and coincident with P at the instant shown

$i = \sqrt{-1}$. It is worth noting that when three points O, B and C are under discussion the following statement is true: "The position of C relative to O is equal to the position of B relative to O plus the position of C relative to B." Referring to *Fig.* 1*c* the same statement in symbol form is

The *velocity* of one point relative to another is the time rate of change of relative position and is a vector quantity which can be obtained by taking the first derivative of the relative position vector with respect to time.

$$V_{CO} = \frac{d}{dt}(P_{CO}) = \frac{d}{dt}([OC]e^{i\theta}) = i[OC]e^{i\theta}\frac{d\theta}{dt} + e^{i\theta}\frac{d[OC]}{dt} \qquad (2)$$

Referring to *Fig.* 1*a*, $d\theta/dt$ is the angular velocity of the vector OC, usually designated by the symbol ω, and $d[OC]/dt$ is the time rate of change in length of vector OC. The velocity of C relative to O is then the sum of two components, $[OC]\omega$ perpendicular to OC and $d[OC]/dt$ parallel to OC. In the special case illustrated by *Fig.* 1*b*, O is the center of curvature, at the instant, of the path followed by C relative to O. $d[OC]/dt$ is therefore zero and V_{CO} is simply $[OC]\omega$, in the direction as shown if θ is increasing (i.e. if ω is counterclockwise), and in the opposite direction if θ is decreasing.

Of particular interest is the relative velocity between two points on the same rigid body. In *Fig.* 2*a*, $V_{BC} = [CB]\omega$ where ω is the angular velocity of CB and therefore of the body.

If three points, not necessarily on the same body, are under discussion, the relation between their velocities, obtained by differentiating Equation 1 with respect to time, is

$$V_{CO} = V_{BO} +\!\!\rightarrow V_{CB} \qquad (3)$$

Often it is necessary to know the relative velocity between coincident points located on different bodies moving independently. In *Fig.* 3 the irregular outline represents a body in plane motion, O being any point of that body, p is a point in motion relative to the body and tracing on the body the path with instantaneous center of curvature C, and P is the point on the body coincident with p at the instant. Expressions similar to Equation 3 may be written

$$V_{pO} = V_{CO} +\!\!\rightarrow V_{pC}$$
$$V_{pO} = V_{PO} +\!\!\rightarrow V_{pP}$$

Solving simultaneously for V_{pP}

$$V_{pP} = V_{CO} +\!\!\rightarrow V_{pC} -\!\!\rightarrow V_{PO}$$

$$= \frac{d}{dt}([OC]e^{i\theta}) + \frac{d}{dt}([Cp]e^{i\phi}) - \frac{d}{dt}([OP]e^{i\beta})$$

$$= i[OC]e^{i\theta}\frac{d\theta}{dt} + i[Cp]e^{i\phi}\frac{d\phi}{dt} - i[OP]e^{i\beta}\frac{d\beta}{dt}$$

But $d\beta/dt = d\theta/dt$ since OC and OP are both lines fixed to the body. Then

$$V_{pP} = i([OC]e^{i\theta} - [OP]e^{i\beta})\frac{d\theta}{dt} + i[Cp]e^{i\phi}\frac{d\phi}{dt}$$

But from the figure $[OC]e^{i\theta} - [OP]e^{i\beta} = -[Cp]e^{i\phi}$ at the instant considered, therefore

$$V_{pP} = i[Cp]e^{i\phi}\left(\frac{d\phi}{dt} - \frac{d\theta}{dt}\right)$$

Denoting $d\phi/dt$ by ω', the angular velocity of $[Cp]$, and $d\theta/dt$ by ω, the angular velocity of the body,

$$V_{pP} = [Cp](\omega' - \omega) \qquad (4)$$

perpendiculuar to Cp. Particular attention should be given to Equation 4. It is a common error to confuse the velocity of p relative to the coincident point of the path (point P) with the velocity of p relative to the center of curvature

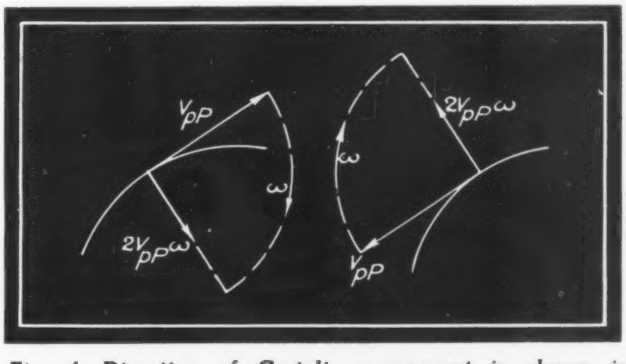


Fig. 4—Direction of Coriolis component is shown in relation to relative linear and angular velocities

of the path (point C). Comparing the two, $V_{pP} = [Cp]\ (\omega' - \omega)$ and $V_{pC} = [Cp](\omega')$ If the body is stationary or has a motion of pure translation then $\omega = O$ and the two are identical, which is the cause of the confusion.

The *acceleration* of one point relative to another is the time rate of change of the relative velocity, and is a vector quantity obtained by taking the first derivative of the relative velocity vector with respect to time. Referring again to *Fig.* 1*a*

$$V_{CO}=i[OC]e^{i\theta}\frac{d\theta}{dt}+e^{i\theta}\frac{d[OC]}{dt} \qquad (2)$$

$$A_{CO}=\frac{d(V_{CO})}{dt}$$

$$=-[OC]e^{i\theta}\left(\frac{d\theta}{dt}\right)^2+i[OC]e^{i\theta}\frac{d^2\theta}{dt^2}+i\,e^{i\theta}\left(\frac{d\theta}{dt}\right)\left(\frac{d[OC]}{dt}\right)$$

$$+e^{i\theta}\left(\frac{d^2[OC]}{dt^2}\right)+i\ e^{i\theta}\left(\frac{d\theta}{dt}\right)\left(\frac{d[OC]}{dt}\right)$$

$$=-[OC]e^{i\theta}\left(\frac{d\theta}{dt}\right)^2+i[OC]e^{i\theta}\frac{d^2\theta}{dt^2}$$

$$+2\,i\,e^{i\theta}\left(\frac{d\theta}{dt}\right)\left(\frac{d[OC]}{dt}\right)+e^{i\theta}\frac{d^2[OC]}{dt^2} \qquad (5)$$

In the special case of *Fig.* 1*b* where O is the center of

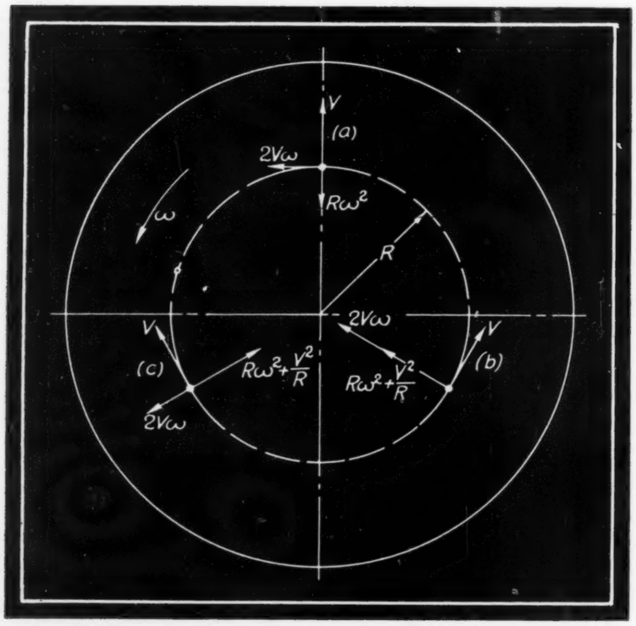


Fig. 5—Vectors show how skater on a revolving rink is affected by forces due to the Coriolis component

curvature of the path of C relative to O at the instant under consideration, $d[OC]/dt = O$, and $d^2[OC]/dt^2 = O$, then

$$A_{CO}=-[OC]e^{i\theta}\left(\frac{d\theta}{dt}\right)^2+i[OC]e^{i\theta}\frac{d^2\theta}{dt^2} \qquad (6)$$

where $d^2\theta/dt^2$ is the angular acceleration of OC, usually designated by the symbol α. Then

$$A_{CO}=[OC]\omega^2+\!\!\!\rightarrow[OC]\alpha \qquad (7)$$

The negative sign of the first term of Equation 6 shows that the component $[OC]\omega^2$ is directed from C toward O, normal to the relative path. It is therefore called the normal component of relative acceleration, A^n_{CO}. The component $[OC]\alpha$ is tangent to the relative path and is called the tangential component of relative acceleration, A^t_{CO}. It is in the same direction as V_{CO} if V_{CO} is increasing, in the opposite direction if V_{CO} is decreasing. Equation 7 may be written $A_{CO} = A^n_{CO} +\!\!\!\rightarrow A^t_{CO}$. It should be noted that since $V_{CO} = [OC]\omega$, the normal component of relative acceleration may be expressed in any of the following ways:

$$A^n_{CO}=[OC]\omega^2=(V_{CO}\omega)=V_{CO}^2[OC] \qquad (8)$$

Equation 7 applies directly to two points located on the same rigid body. In *Fig.* 2*a*,

$$A_{BC}=A^n_{BC}+\!\!\!\rightarrow A^t_{BC}=[CB]\omega^2+\!\!\!\rightarrow[CB]\alpha$$

where ω and α are, respectively, the angular velocity and angular acceleration of the body.

Upon differentiating Equation 3 with respect to time,

$$A_{CO}=A_{BO}+\!\!\!\rightarrow A_{CB} \qquad (9)$$

Equation 4 gives the relative velocity between coincident points located on different bodies. For the relative acceleration between coincident points an analogous expression is needed. In *Fig.* 3, from Equation 9, it is possible to write:

$$A_{pO}=A_{CO}+\!\!\!\rightarrow A_{pC}$$

also $\quad A_{pO}=A_{PO}+\!\!\!\rightarrow A_{pP}.$

Then $\quad A_{pP}=A_{CO}+\!\!\!\rightarrow A_{pC}-\!\!\!\rightarrow A_{PO}$

$$=[OC]\omega^2+\!\!\!\rightarrow[OC]\alpha+\!\!\!\rightarrow[Cp](\omega')^2+\!\!\!\rightarrow[Cp]\alpha'$$

$$+\!\!\!\rightarrow[OP]\omega^2+\!\!\!\rightarrow[OP]\alpha$$

Since $[OC] \rightarrow [OP] = -[Cp]$ the above expression becomes

$$A_{pP}=[Cp](\alpha'-\alpha)+\!\!\!\rightarrow[Cp](\omega'^2-\omega^2) \qquad (10)$$

After substitution of $(\omega' - \omega) + \omega$ for ω' Equation 10 reduces to the following more convenient form:

$$A_{pP}=[Cp](\alpha'-\alpha)+\!\!\!\rightarrow[Cp](\omega'-\omega)^2+\!\!\!\rightarrow2[Cp](\omega'-\omega)\omega \qquad (11)$$

Since, from Equation 4, $V_{pP} = [Cp]\ (\omega' - \omega)$ this can be written

$$A_{pP}=[Cp](\alpha'-\alpha)+\!\!\!\rightarrow[Cp](\omega'-\omega)^2+\!\!\!\rightarrow2V_{pP}\omega \qquad (12)$$

(*Continued on Page* 162)

Simplifying Design of Volute Springs

By A. M. Wahl
Westinghouse Research Laboratories

—Photo courtesy Baldwin Loco. Wks.

Fig. 1—Advantages of volute spring for military equipment include damping characteristics and increasing stiffness under high loads

BECAUSE of increasing use, particularly in the military field, the volute spring has reached a position of importance in design. Formerly the complexity of formulas available, due primarily to the non-linear load-deflection characteristic, has involved a great deal of work in developing such springs. In this article, equations and curves will be presented which provide for quick and simple calculations.

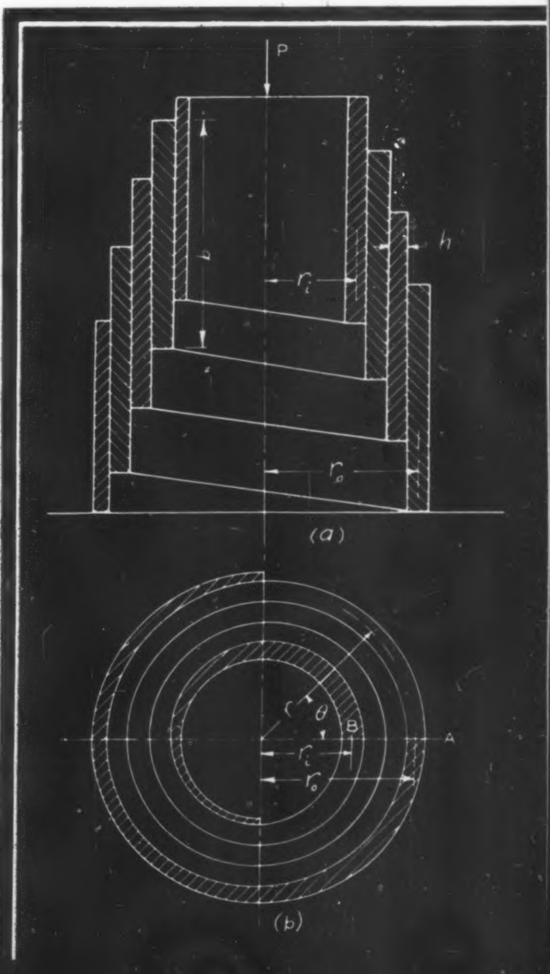
In manufacturing volute springs, a relatively wide and thin bar or blade is wound on a mandrel to form the shape shown in *Fig.* 1 and indicated by the cross section in *Fig. 2a*. Such a spring will have a constant helix angle and a variable coil radius. The plan view is shown in *Fig. 2b* and the developed shape in *Fig.* 3. When axially loaded the elements of the spring are subject to torsion stress in essentially the same manner as a rectangular bar helical compression spring. In the latter figure the constant helix angle α is indicated for the unloaded condition while the shaded areas near the ends represent inactive turns. These are also indicated in *Fig. 2b*.

Among the advantages of this type of spring are the following: Compactness, ease of manufacture, damping produced by friction between turns, a spring rate which increases at high deflections and thus tends to protect the spring against overload. These advantages are partially offset by an unfavorable stress distribution within the spring which tends to lower the endurance or fatigue strength.

The curved, load-deflection characteristic of volute springs is due primarily to the fact that above a certain load the coils are apt to "bottom" or to come in contact with the supporting plate. This bottoming reduces the number of active coils as well as their average radius, thus increasing the spring stiffness.

Method of calculation presented herein is based on the assumption that each element of the volute spring may be considered a portion of an axially loaded helical spring of the same coil radius and having a rectangular cross section[1]. Friction between adjacent coils is thus neglected; also certain additional or secondary stresses are present which are difficult to calculate. Some of these additional stresses arise from the fact that the resultant load P (*Fig. 2a*) in general will not be axial as assumed in the calculations but will be displaced from the axis of the spring, thus giving rise to additional stresses caused by this eccentricity. In addition, certain stresses known as *cone* and *arch* stresses are present which may modify the results[2]. For calculating deflections, the present method is probably close

Fig. 2—Sectional views of a volute spring



[1] For a comprehensive discussion of volute spring calculations, see article by B. Sterne, "Characteristics of the Volute Spring," *Journal* S.A.E., June, 1942, Page 221. See also paper by H. O. Fuchs, "Notes on Secondary Stresses in Volute Springs," presented at the 1942 annual A.S.M.E. meeting.

[2] See paper by Fuchs, listed in Footnote 1.

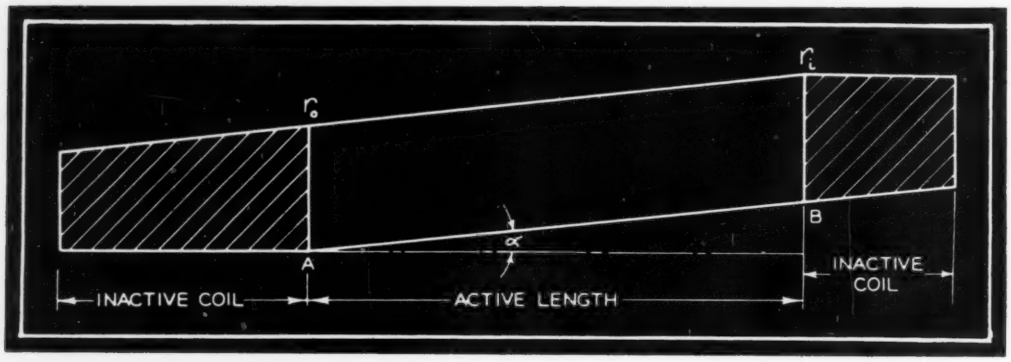


Fig. 3 — Developed volute spring indicating inactive and active lengths of spring

enough for most practical purposes but it should be borne in mind that the stress calculations are only approximate and may require modification when more data are available.

Bottoming Loads: Referring to *Fig.* 4 which represents the developed center line of the blade of a volute spring, the spring at zero load is indicated by the line *AB*. In this the ordinate represents the height of the blade center line, and the abscissa the distance from outer end *A*. At moderate loads before the outer end starts to bottom, the developed length will be represented by the dashed line *AE*, while at heavy loads when a portion *AC* of the outer coil is bottomed the developed length is represented by *ACD*.

Stiffens with Increasing Load

Up to a certain load P_1 (which will be called the initial bottoming load) at which the outer coil just starts to bottom, the load-deflection characteristic will be a straight line as indicated in *Fig.* 5. Above this load, as the coils bottom, the spring becomes stiffer as indicated and the load-deflection characteristic curves upward.

In calculating the initial bottoming load it will be assumed that the coil radius r at any angle θ from the built-in outer end A (*Fig.* 2*b*) may be represented approximately by a spiral. This will be sufficiently accurate for most practical purposes. Thus

$$r=r_0\left(1-\frac{\beta\theta}{2\pi n}\right) \qquad (1)$$

where

$$\beta=\frac{r_0-r_i}{r_0} \qquad (2)$$

r_0, r_i are the radii at the beginning and end, respectively, of the active portion of the spring (*Fig.* 2) and n is the number of active coils.

The deflection per turn of a helical spring of narrow rectangular cross section, where the long side of the section is parallel to the spring axis and where the width b (*Fig.* 2*a*) is greater than 2.7h, as is usually the case in volute springs, is given with sufficient accuracy by the following equation[3]:

$$\delta_t=\frac{6\pi Pr^3}{Gbh^3\left(1-.63\frac{h}{b}\right)} \qquad (3)$$

[3] See writer's article, Machine Design, April, 1938.

where P = load on spring, h = thickness of blade, b = blade width, G = modulus of rigidity, r = coil radius.

In a small angle $d\theta$, the increment of the deflection $d\delta$ will be equal to δ_t multiplied by $d\theta/2\pi$. Hence, using Equation 3

$$d\delta=\delta_t\frac{d\theta}{2\pi}=\frac{3Pr^3d\theta}{Gbh^3\left(1-.63\frac{h}{b}\right)} \qquad (4)$$

In this r = mean coil radius at angle θ (*Fig.* 2*b*).

From *Fig.* 4, bottoming of the outer coil may be expected to start when the slope $d\delta/ds$ at the outer mean radius r_0

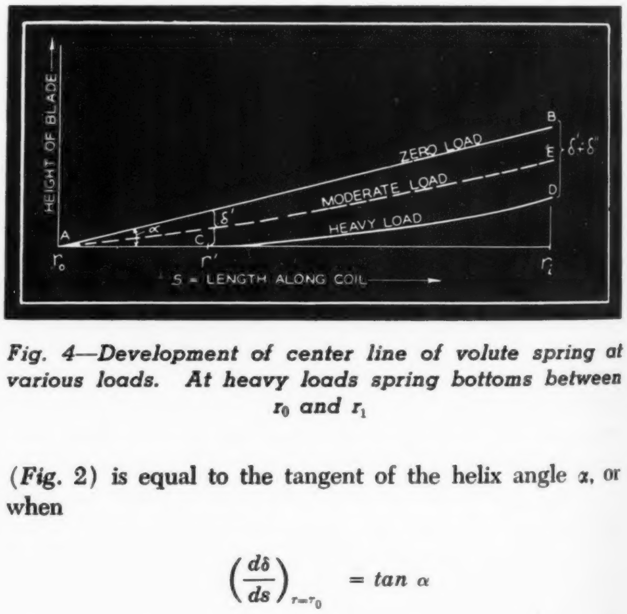


Fig. 4—Development of center line of volute spring at various loads. At heavy loads spring bottoms between r_0 and r_1

(*Fig.* 2) is equal to the tangent of the helix angle α, or when

$$\left(\frac{d\delta}{ds}\right)_{r=r_0}=\tan\alpha$$

Since α is usually small in practical volute springs the tangent of the angle may with sufficient accuracy be taken equal to the angle in radians. Taking $ds = rd\theta$ and $\tan\alpha = \alpha$, this condition becomes

$$\left(\frac{d\delta}{rd\theta}\right)_{r=r_0}=\alpha \qquad (5)$$

Putting $r = r_0$ in Equation 4, and substituting in Equation 5, the initial bottoming load P_1 becomes

$$P_1=\frac{Gbh^3\alpha\left(1-.63\frac{h}{b}\right)}{3r_0^2} \qquad (6)$$

In this the helix angle α is expressed in radians (degrees divided by 57.3).

Deflection when $P < P_1$: To calculate the deflection δ for loads P that are less than the initial bottoming load P_1, Equations 1 and 4 may be used. Substituting the value of r given by Equation 1 in Equation 4, the increment of deflection becomes

$$d\delta = \frac{3Pr_0^3\left(1 - \frac{\beta\theta}{2\pi n}\right)^3 d\theta}{Gbh^3\left(1 - .63\frac{h}{b}\right)} \quad \text{.........................(7)}$$

Integrating this between the limits $\theta = 0$ and $\theta = 2\pi n$ where n is the number of active coils, the total deflection (for loads under the initial bottoming load) may be expressed as

$$\delta = \frac{P}{P_1}(2\pi n r_0 \alpha K_1)\text{, when } P < P_1 \quad \text{......................(8)}$$

where α = helix angle *in radians*, P_1 is given by Equation 6, and

$$K_1 = 1 - \frac{3}{2}\beta + \beta^2 - \frac{\beta^3}{4} \quad \text{.............................(9)}$$

Values of K_1 are plotted as functions of $\beta = (r_0 - r_i)/r_0$ in *Fig.* 6. The values of r_0 and r_i in this expression depend on the design of the end coils (*Fig.* 2). Where these latter are tapered as indicated in *Fig.* 2, three-fourths turn at each end is frequently considered inactive, but this figure may be changed as further test data become available.

Thus to calculate deflection at any load P less than P_1 the simple formula of Equation 8 may be used, the value K_1 being read from the curve of *Fig.* 6.

Deflection for Loads above Initial Bottoming Load P_1: Where the load P is above the bottoming load P_1, the deflection δ may be considered as composed of two

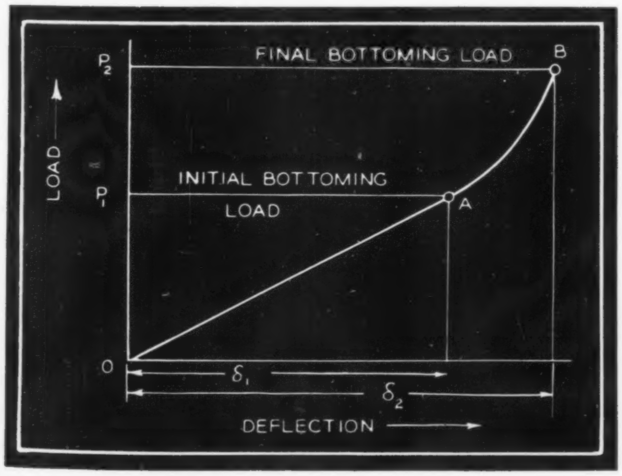


Fig. 5—Load-deflection characteristic of volute spring

parts, e.g., a part δ' (*Fig.* 4) due to the compression of the bottomed portion *AC* of the spring and a part δ'' due to the deflection of the free portion *CD*. Assuming that the coils have bottomed to a radius r' and angle θ' as indicated in *Fig.* 4, then from the condition $d\delta/ds = \alpha$ at the radius $r = r'$ and by proceeding as before the following is obtained:

$$c' = 2\sqrt{\frac{\alpha Gbh\left(1 - .63\frac{h}{b}\right)}{3P}} \quad \text{........................(10)}$$

In this, $c' = 2r'/h$ = spring index at $r = r'$.

Also by taking $r = r'$ and $\theta = \theta'$ in Equation 1, the angle θ' may be expressed as follows:

$$\theta' = \frac{2\pi n}{\beta}\left(1 - \frac{c'}{c_0}\right) \quad \text{.................................(11)}$$

where $c_0 = 2r_0/h$ = spring index at $r = r_0$.

Assuming as before that $\tan\alpha = \alpha$, the deflection δ' is given by

$$\delta' = \int_0^{\theta'} \alpha r d\theta \quad \text{...(12)}$$

Using Equation 1 in this and integrating,

$$\delta' = \alpha r_0\theta'\left(1 - \frac{\beta\theta'}{4\pi n}\right) \quad \text{................................(13)}$$

By using Equations 6, 10 and 11 this equation may be expressed in terms of the ratio P/P_1 as follows:

$$\delta' = \frac{\pi\alpha r_0 n}{\beta}\left(1 - \frac{P_1}{P}\right) \quad \text{..............................(14)}$$

The deflection δ'' will be obtained by summing up the elementary deflections $d\delta$ between the limits $\theta = \theta'$ and $\theta = 2\pi n$ Thus, using Equation 7,

$$\delta'' = \int_{\theta'}^{2\pi n} \frac{3Pr_0^3(1 - \beta\theta/2\pi n)^3 d\theta}{Gbh^3(1 - .63h/b)} \quad \text{....................(15)}$$

Integrating this, simplifying and adding to the value of δ' given by Equation 14, the total deflection δ becomes for $P > P_1$:

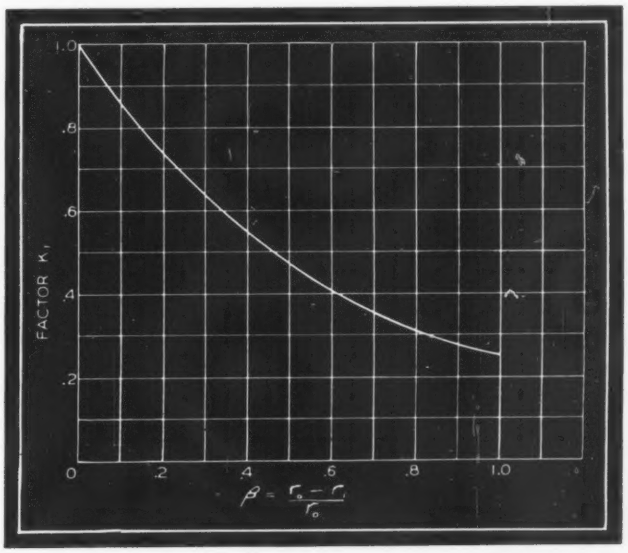


Fig. 6—Curves for finding factor K_1 as function of β

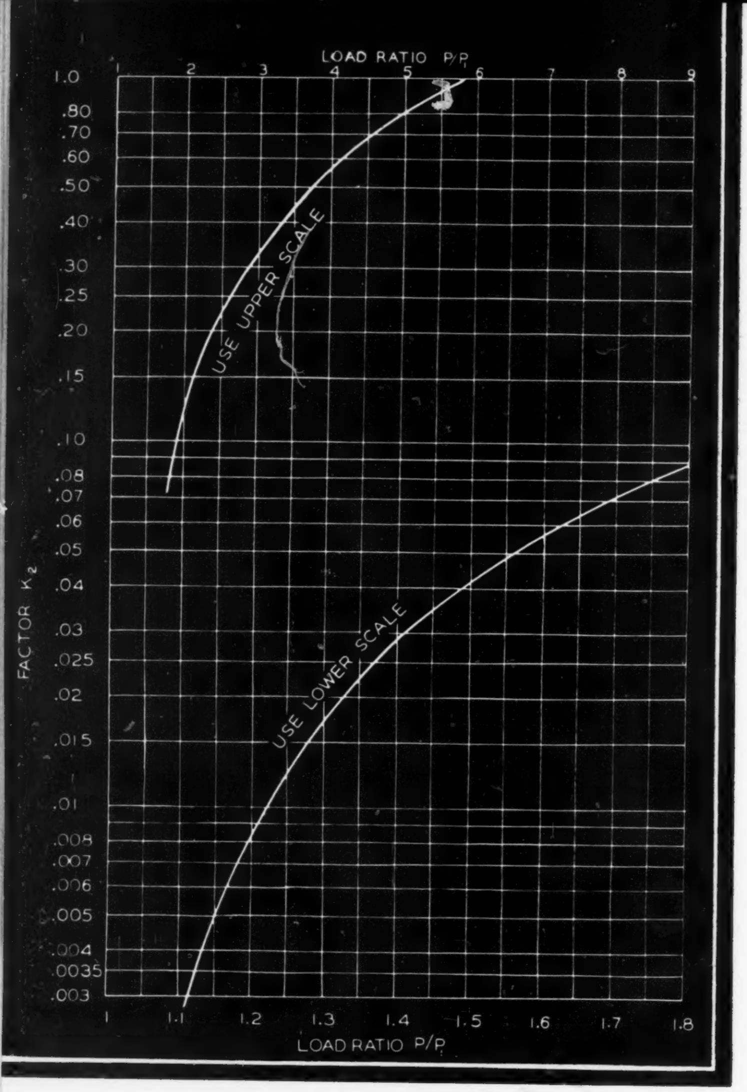


Fig. 7—Curves for finding factor K_2

$$\delta = \delta' + \delta'' = 2\pi n r_0 \alpha \left(\frac{P}{P_1} K_1 - \frac{K_2}{\beta} \right) \quad \ldots\ldots (16)$$

where K_2 is a function of the ratio P/P_1.

$$K_2 = \frac{1}{2}\left(\frac{P_1}{2P} + \frac{P}{2P_1} - 1 \right) \quad \ldots\ldots (17)$$

Values of K_2 are given as functions of P/P_1, in *Fig.* 7. By using this curve and that of *Fig.* 6, the deflection at any load P may easily be calculated. In this manner the complete load-deflection characteristic of the spring may be obtained.

To find the load P_2 at which all coils bottom the procedure is as follows. From Equation 10, by using the expression for P_1 given by Equation 6,

$$\frac{c'}{c_0} = \frac{r'}{r_0} = \sqrt{\frac{P_1}{P}} \quad \ldots\ldots (18)$$

Bottoming of all active coils will occur when $r' = r_i$ and $P = P_2$. Using Equation 18 and taking $\beta = (r_0 - r_i)/r_0$ the final bottoming load P_2 becomes

$$P_2 = \frac{P_1}{(1-\beta)^2} = P_1 \left(\frac{r_0}{r_i} \right)^2 \quad \ldots\ldots (19)$$

The deflection δ_2 at the load P_2 is obtained by taking $\theta' = 2\pi n$ in Equation 12 and integrating, using the value of r given by Equation 1. This also gives the difference between free and solid height:

$$\delta_2 = \int_0^{2\pi n} \alpha r_0 \left(1 - \frac{\beta\theta}{2\pi n} \right) d\theta = 2\pi n r_0 \alpha \left(1 - \frac{\beta}{2} \right) \quad \ldots\ldots (20)$$

Solving this for α the helix angle in terms of δ_2 is

$$\alpha = \frac{\delta_2}{2\pi n r_0 \left(1 - \frac{\beta}{2} \right)} \quad \ldots\ldots (21)$$

Since the free and solid heights of the spring are known, the helix angle α (in radians) may be calculated from this equation. The deflection δ_1 at which initial bottoming occurs is obtained from Equation 8 taking $P = P_1$. This gives

$$\delta_1 = 2\pi n r_0 \alpha K_1 \quad \ldots\ldots (22)$$

To construct an approximate load-deflection curve for any spring it is only necessary to calculate P_1, P_2 δ_1 and δ_2 from Equations 6, 19, 20 and 22. A straight line is then drawn between the origin and point A representing P_1 and δ_1 (*Fig.* 5). Point B (representing P_2 and δ_2) is connected to A by a smooth curve concave upward. For greater accuracy, if desired, additional points on this curve may be calculated from Equation 16. Thus the load-deflection diagram may be determined simply.

Stress Calculations Are Approximate

STRESS: To calculate the stress, the formulas for rectangular bar helical springs will be used, modified to apply to the volute spring. As mentioned previously, these stresses should be considered only as first approximations because additional secondary stress usually will be present. Where the load P is less than the initial bottoming load P_1, the peak stress will occur at the maximum radius $r = r_0$. Using the approximate equation for a rectangular bar spring with $b > 3h$ and with the long side of the rectangle parallel to the spring axis as given in a previous article[4], the maximum shear stress τ (where $P \lesseqgtr P_1$) becomes

$$\tau = \frac{3P(c_0+1)}{2hb\left(1 - .63\frac{h}{b} \right)} \quad \text{when } P < P_1 \quad \ldots\ldots (23)$$

In this $c_0 = 2r_0/h$ = spring index at $r = r_0$. Where h/b is small, i.e., where the blade is wide compared to the thickness, the term $1 - .63h/b$ may be taken as unity. This gives, approximately,

$$\tau = \frac{3P(c_0+1)}{2hb} \quad \ldots\ldots (24)$$

Where $P > P_1$ the maximum shear stress τ will occur at $r = r'$ where r' is the radius at which bottoming occurs. Thus Equation 23 may be used, putting $c_0 = c'$ where $c' = 2r'/h$ = spring index at $r = r'$. This gives

$$\tau = \frac{3P(c'+1)}{2hb\left(1 - .63\frac{h}{b} \right)}, \quad \text{when } P > P_1 \quad \ldots\ldots (25)$$

[4] MACHINE DESIGN, April, 1938.

Since from Equation 18, $c' = c_0 \sqrt{P_1/P}$, by substitution of this in Equation 25, the stress at any load P (for $P > P_1$) becomes

$$\tau = \frac{3P\left(c_0\sqrt{\frac{P_1}{P}}+1\right)}{2hb\left(1-.63\frac{h}{b}\right)} \qquad (26)$$

When final bottoming occurs, the load $P = P_2$. Using the value of P_1/P_2 given by Equation 19 in Equation 26 the peak stress τ_2 at the final bottoming load P_2 may be expressed by

$$\tau_2 = \frac{3P_2(c_i+1)}{2hb\left(1-.63\frac{h}{b}\right)} \qquad (27)$$

where $c_i = 2r_i/h =$ spring index at $r = r_i$.

Substituting in this the value of P_2 given by Equation 19 and the value of P_1 given by Equation 6, the stress τ_2 for final bottoming reduces to the simple expression

$$\tau_2 = \frac{2G\alpha(c_i+1)}{c_i^2} \qquad (28)$$

These formulas include the effect of bar curvature. If it is desired to neglect this effect where static loading is present, the calculation may be made using the same equations (23 to 28), but reducing the expression in the parenthesis of the numerator by unity. (Thus in Equation 23, to do this c_0 is taken instead of $c_0 + 1$ in the numerator). For most volute springs this will not make a great deal of difference, however.

Application to Practical Design

EXAMPLE: As an example of the use of these equations in practical design a volute spring with the following dimensions may be considered: $r_0 = 2\frac{1}{2}$-inch, $r_i = 1\frac{1}{4}$-inch, $h = \frac{1}{4}$-inch, $b = 5$-inch $=$ solid height, free height $= 7\frac{1}{2}$-inch, $c_0 = 2r_0/h = 20$, $c_i = 2r_i/h = 10$, $n = 4 =$ number of active coils, $\beta = (r_0 - r_i)/r_0 = .5$.

The solid deflection δ_2 will be the difference between the free and solid heights; thus $\delta_2 = 2\frac{1}{2}$-inch. From Equation 21 the helix angle α is

$$\alpha = \frac{\delta_2}{2\pi n r_0\left(1-\frac{\beta}{2}\right)} = \frac{2.5}{2\pi\times 4\times 2.5\times .75} = .0531 \text{ radians}$$

Taking $G = 11.5(10)^6$ for steel, the peak shear stress with the spring solid becomes, from Equation 28,

$$\tau_2 = \frac{2\times 11.5\times(10)^6\times .0531\times 11}{(10)^2} = 135000 \text{ psi}$$

The initial bottoming load P_1 is, from Equation 6,

$$P_1 = \frac{11.5\times(10)^6\times 5\times(.25)^3\times .0531\times .969}{3(2.5)^2} = 2460 \text{ lb}$$

Shear stress at the initial bottoming load P_1 from Equation 23 is,

$$\tau_1 = \frac{3\times 2460\times 21}{2\times .25\times 5\times .969} = 64000 \text{ psi}$$

From Equation 19 the final load P_2 is found:

$$P_2 = \frac{2460}{(.5)^2} = 9840 \text{ lb}$$

The deflection δ_1 at the initial bottoming load P_1 is given by Equation 22, using the value of $K_1 = .47$ given by *Fig.* 6 for $\beta = .5$. This gives

$$\delta_1 = 2\pi n r_0 \alpha K_1 = 2\pi\times 4\times 2.5\times .0531\times .47 = 1.57 \text{ in.}$$

The value δ_2 for the final bottoming load P_2 will be the difference between the free and solid height, i.e., $\delta_2 =$ $7.5 - 5 = 2.5$-inch. Knowing δ_1, δ_2, P_1, and P_2 a load deflection curve similar to *Fig.* 5 may be plotted for this particular spring. A similar load-stress curve may be plotted, since the stress will vary linearly with load up to the initial bottoming P_1. The stress at any load between P_1 and P_2 may be calculated from Equation 26. In this manner the complete load-stress and load-deflection diagrams as given in *Fig.* 9 are obtained for this case. From these diagrams, if desired, a stress-deflection curve may also be plotted.

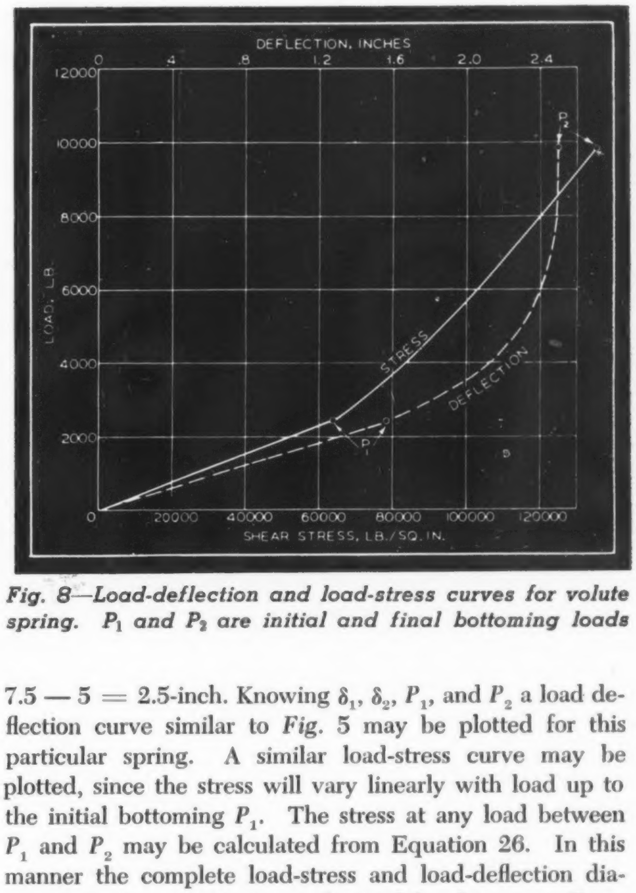


Fig. 8—Load-deflection and load-stress curves for volute spring. P_1 and P_2 are initial and final bottoming loads

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CORRECTION: In the article "Bearing Design as Affected by Lubrication Theory" (M. D., January, 1943), Equation 2 on Page 78 should read:

$$c = 1 + 2\left(\frac{D}{B}\right)^2 \qquad (2)$$

Broken type caused an error to appear in a number of copies. Term D/B should be squared as shown.

Evaluating NE Steels*

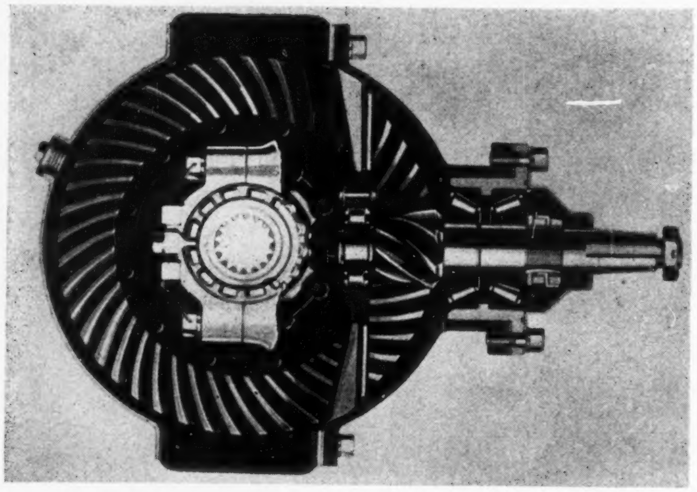
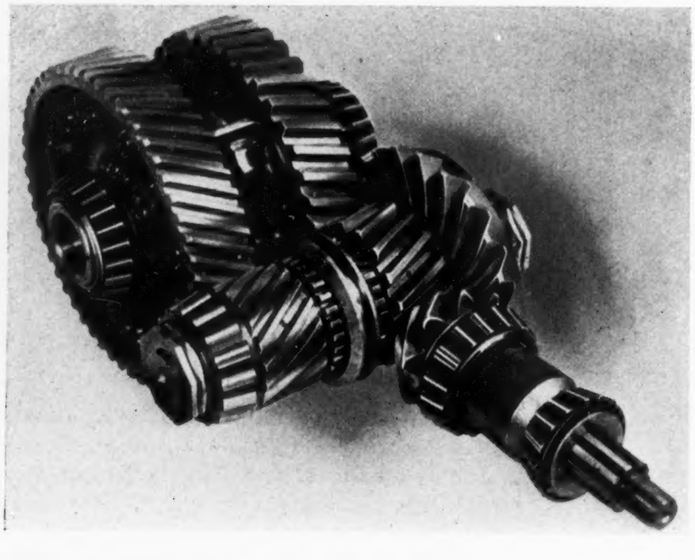


Fig. 1—Spiral bevel gearing for a truck rear axle assembly employs nine parts of NE 8720, carburized and hardened

Fig. 2—Double-reduction, two-speed gear unit utilizes fifteen parts of carburized and hardened NE steels



By Roy W. Roush

Metallurgist
Timken-Detroit Axle Co.

AS A MEANS of evaluating the National Emergency steels, much emphasis is placed on hardenability. This provides a rapid and convenient means of determining the hardening properties and a first indication of the possibilities of any steel, but to draw all conclusions on the basis of hardenability is neglecting the important consideration of ductility.

It is generally conceded that a steel will perform best if it has been hardened all the way through to its maximum hardness, and then tempered back to the hardness desired. As tensile strength is closely proportional to hardness, it can be said that hardenability is a measure of strength, or rather the capacity for strength, especially of different portions of a cross section. The elastic limit and endurance limit are proportional to hardness provided initial hardening was complete, but are not always consistent after incomplete initial hardening.

Hardenability tests have been an efficient yardstick in building the NE steel specifications and are probably the only ones suitable, but the real value of a steel must be confirmed by laboratory and performance tests. This is being done as rapidly as possible, and steels not satisfactory are either being altered or deleted.

By far the most popular of the NE steels have been the 8600 series and the 8700 series. In the carburizing grades either makes good gears. While there are only five points difference in molybdenum, the 8700 series is probably better for heavy-duty gears. The 8630 is used for a number of structural parts. It can be water-quenched and, between 200 and 400 brinell, shows good fatigue properties.

The extremely critical condition in molybdenum has forced greater reductions in this element and the 8700 series except for the 8720 is being deleted. The 8817 and 8949 and also the 8547, 8339 and 8442 likewise have been deleted as a molybdenum conservation measure.

From actual production experience with NE steels, there have been a few cases reported of flakes or bursts in large forging bars. A condition remedied by slow cooling after rolling. Mills have learned that the same care and slow cooling required for the S.A.E. alloy steels are required for the NE steels. In forging there has been no great difference between the old S.A.E. alloy steels and any of the NE steels.

A number of manufacturers have reported no

*From a paper presented before the S.A.E. Detroit meeting, January 13, 1943.

difference in machining between the NE steels and the former S.A.E. steels Large lots, in some cases, have gone through production lines without the operators knowing there had been a change in materials. In the Timken-Detroit plant approximately 100,000 spiral bevel rear axle drive gear sets, *Fig.* 1, have been made from NE 8720 steel, involving some twenty 100-ton heats. Machining tests show little difference, in the number of gears per cutter grind, between SAE 4620 and 4120 and NE 8720. In hobbing splines from NE 8744, with hardness between 400 and 444 brinell, a slight reduction in pieces per grind and pieces per cutter was encountered in comparison with SAE 3240 and 4340. In *Fig.* 2 is shown a double-reduction two-speed gear unit in which NE steel is utilized.

At hardness of 200 to 350 brinell, machining of NE steels in general is comparable to the corresponding S.A.E. grade:

NE Steels	Comparable S.A.E. Grades
8630	3130 and 4130
8735 to 8740	3135 and 4140
8740 to 8745	3240 and 4340

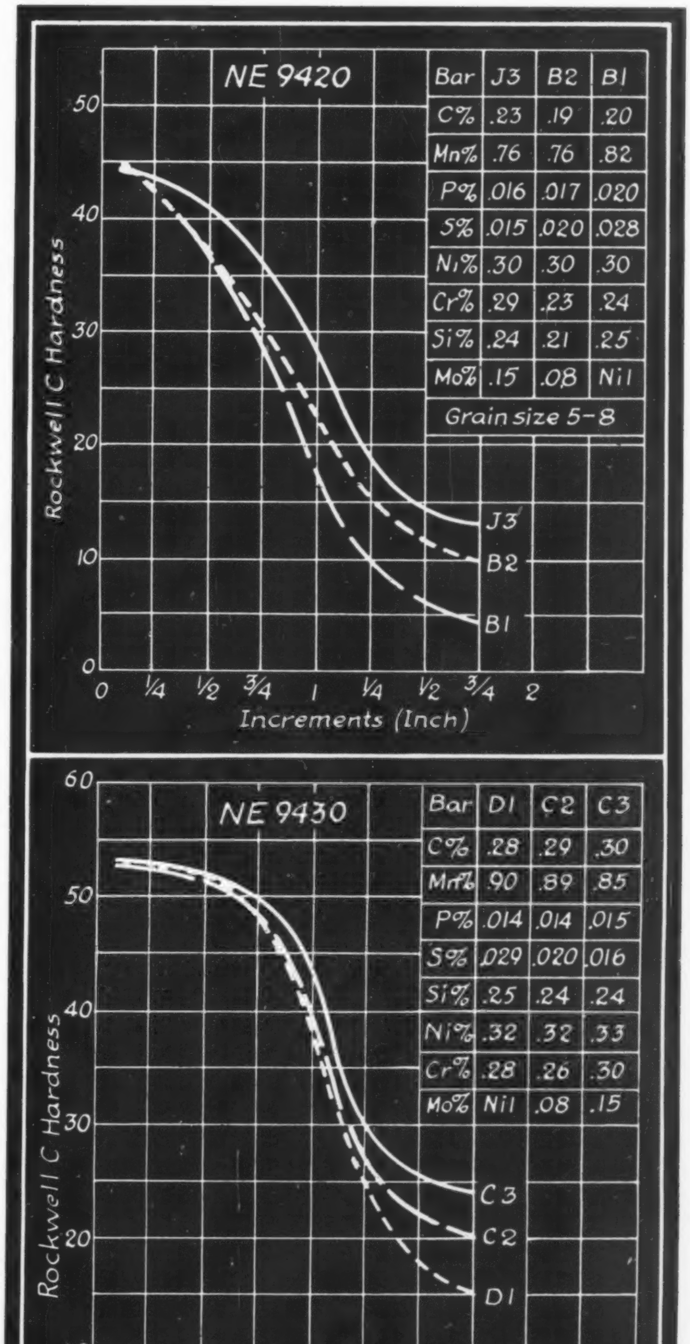
For structural steels, both oil and water hardening, a large tonnage of the 8600 and 8700 series has been used. In the manganese-molybdenum grades NE 8339 and 8442, although now deleted from standard lists, have been used extensively. Also the use of 9442 for a number of parts is increasing. In the hardness range 200-400 the available physical properties show that all of these steels are satisfactory, with good strength and toughness.

Welding Compares Favorably

Considerable work has been done on different types of welding on a limited number of NE steels. NE 8630 seems to be one of the best suited. It has replaced 4130 in a number of applications. Aircraft tubing has been welded successfully, both by oxyacetylene gas flame and metallic arc. The same general technique can be used for either steel. Using a mild steel rod, the maximum hardness reached in the heat-affected zone is approximately the same for both steels. Warping and shrinking characteristics are similar, likewise susceptibility to cracking. The tensile strength of welded joints, both as welded and heat treated, is equivalent for both steels. Each fails in the same manner. While the 8630 is the only NE steel on which an appreciable amount of welding information is available, it is estimated that 9430 will show comparable results.

No discussion dealing with steels, poor in alloy, would be complete without considering the effects of special alloy addition agents. After about four years of experience with a vanadium-type additive treatment in the carburizing and structural grades of steel, showing unbelievable results, this company could not sit back and think of it all as just a memory. Since vanadium has been restricted the use of these specially treated steels has been continued. We believe today that a proper alloy addition agent will give to the 9400 series the qualities which will make it a high-grade steel. Recently, one heat of 9420 modified with

Fig. 3—Hardenability curves showing the effect of reducing the molybdenum content of NE 9420 and NE 9430. Chemical compositions for the various test bars are shown in the tabulations. Jominy L-type bars, not normalized, quenched at 1650F were used for the 9420 tests. Similar type bars were used for the 9430 tests



an additive treatment which was made into spiral-bevel, rear-axle drive gears passed maximum requirements on the dynamometer test.

A good report was received from a large automotive manufacturer on dynamometer testing of carburized and hardened transmission gears with following specifications: Pitch, No. 5; pressure angle, 20 degrees; tooth width, 9/16-inch; ratio, 15 to 25; chamfer, none. Gears were carburized, direct quenched and tempered at 380 to 400 degrees Fahr. shot blasted and tested at 1200 r.p.m. pinion speed. Cycles to cause failure at 100,000 pounds per square inch bending stress are as follows:

NE Steels	Cycles
9420 plus grainal	819,000
8620	472,900
9420	204,100
8124	109,100

These tests were made on a specially designed dynamometer to test the gears only and not the complete assembly.

When performance like this is shown repeatedly it cannot be overlooked. Capable committees are at work and testing programs are in progress. Now that the go signal for these special alloy addition agents has been given, greater developments may be expected.

In summarizing the data available on NE steels, it is necessary to proceed with caution. The number of tests reported to date is not large and the results cannot be taken as too conclusive. While specifications are preliminary and subject to change, a start must be made sometime in order to help the war program.

In the gear steels, 9420 is satisfactory as a substitute for 4120 and probably for 4620. It is not quite the equivalent of 4320 or 4820. For most applications reported the 8720 has been satisfactory for these steels. In the water-hardening structural grades, the 8630 can be substituted for 3130 and 4130. Judging from physical properties it is reasonable to believe that 9430 will approach the 8630. The 9442 shows physical properties, including torsion, comparable to 4140.

Indicate Effect of Moly Reductions

The 8739 to 8749 have been good substitutes for 3135 and 4140. Their being deleted in favor of the 8600 series, meaning only a reduction of .05 per cent molybdenum, should not make a great deal of difference but, when alloys are reduced to the minimum, five points of moly *are* five points of moly. To indicate the effects of reducing molybdenum, two sets of hardness curves for 9420 and 9430 are shown in Fig. 3. We believe it is good judgment to retain the 8720 for gears and a number of carburized parts.

From the small amount of data available on the 9600 series it appears to lack ductility. If it is used it should be hardened to between 200 and 400 brinell. Careful and improved heat treating practice will have to make up for some of the weaknesses. There is a lot of work to be done yet on the NE steels, especially on some of the later grades and on the steels treated with addition agents. With a war to win it is our duty to see that this work is done and our military equipment remains the best.

NE Steel Compositions Revised

MODIFICATION in the NE steel compositions made necessary by unexpectedly greater amounts of nickel content in scrap now available were recently approved by representatives of the War Production Board, the Technical Committee on Alloy Steel of American Iron and Steel Institute, and by representatives of the Iron and Steel Division of the Society of Automotive Engineers.

The increase is due partly to influx of new nickel-containing steel scrap as a result of our increasing production of war materials, and partly to conservation measures employed by steel mills.

The accompanying table lists the revised NE steel compositions, superseding those included in MACHINE DESIGN, October 1942, pages 150 and 151.

Number	C	Mn	Si	Cr	Ni	Mo
NE 1330	.28- .33	1.60-1.90	.20- .35	......	.....	.....
NE 1335	.33- .38	1.60-1.90	.20- .35	......	.....	.....
NE 1340	.38- .43	1.60-1.90	.20- .35	......	.....	.....
NE 1345	.43- .48	1.60-1.90	.20- .35	......	.....	.....
NE 1350	.48- .53	1.60-1.90	.20- .35	......	.....	.....
NE 8020	.18- .23	1.00-1.30	.20- .35	......	.....	.10-.20
NE 8442*	.40- .45	1.30-1.60	.20- .35	......	.....	.30-.40
NE 8613	.12- .17	.70- .90	.20- .35	.40- .60	.40-.70	.15-.25
NE 8615	.13- .18	.70- .90	.20- .35	.40- .60	.40-.70	.15-.25
NE 8617	.15- .20	.70- .90	.20- .35	.40- .60	.40-.70	.15-.25
NE 8620	.18- .23	.70- .90	.20- .35	.40- .60	.40-.70	.15-.25
NE 8630	.28- .33	.70- .90	.20- .35	.40- .60	.40-.70	.15-.25
NE 8635	.33- .38	.75-1.00	.20- .35	.40- .60	.40-.70	.15-.25
NE 8637	.35- .40	.75-1.00	.20- .35	.40- .60	.40-.70	.15-.25
NE 8640	.38- .43	.75-1.00	.20- .35	.40- .60	.40-.70	.15-.25
NE 8642	.40- .45	.75-1.00	.20- .35	.40- .60	.40-.70	.15-.25
NE 8645	.43- .48	.75-1.00	.20- .35	.40- .60	.40-.70	.15-.25
NE 8650	.48- .53	.75-1.00	.20- .35	.40- .60	.40-.70	.15-.25
NE 8720	.18- .23	.70- .90	.20- .35	.40- .60	.40-.70	.20-.30
NE 9255	.50- .60	.70- .95	1.80-2.20	......	.....	.....
NE 9260	.55- .65	.75-1.00	1.80-2.20	......	.....	.....
NE 9262	.55- .65	.75-1.00	1.80-2.20	.20- .40	.....	.....
NE 9415	.13- .18	.80-1.10	.40- .60	.20- .40	.20-.50	.08-.15
NE 9420	.18- .23	.80-1.10	.40- .60	.20- .40	.20-.50	.08-.15
NE 9422	.20- .25	.80-1.10	.40- .60	.20- .40	.20-.50	.08-.15
NE 9430	.28- .33	.90-1.20	.40- .60	.20- .40	.20-.50	.08-.15
NE 9435	.33- .38	.90-1.20	.40- .60	.20- .40	.20-.50	.08-.15
NE 9437	.35- .40	.90-1.20	.40- .60	.20- .40	.20-.50	.08-.15
NE 9440	.38- .43	.90-1.20	.40- .60	.20- .40	.20-.50	.08-.15
NE 9442	.40- .45	1.00-1.30	.40- .60	.20- .40	.20-.50	.08-.15
NE 9445	.43- .48	1.00-1.30	.40- .60	.20- .40	.20-.50	.08-.15
NE 9450	.48- .53	1.20-1.50	.40- .60	.20- .40	.20-.50	.08-.15
NE 9537*	.35- .40	1.20-1.50	.40- .60	.40- .60	.40-.70	.15-.25
NE 9540*	.38- .43	1.20-1.50	.40- .60	.40- .60	.40-.70	.15-.25
NE 9542*	.40- .45	1.20-1.50	.40- .60	.40- .60	.40-.70	.15-.25
NE 9550*	.48- .53	1.20-1.50	.40- .60	.40- .60	.40-.70	.15-.25
NE 9630	.28- .33	1.20-1.50	.40- .60	.40- .60	.....	.....
NE 9635	.33- .38	1.20-1.50	.40- .60	.40- .60	.....	.....
NE 9637	.35- .40	1.20-1.50	.40- .60	.40- .60	.....	.....
NE 9640	.38- .43	1.20-1.50	.40- .60	.40- .60	.....	.....
NE 9642	.40- .45	1.30-1.60	.40- .60	.40- .60	.....	.....
NE 9645	.43- .48	1.30-1.60	.40- .60	.40- .60	.....	.....
NE 9650	.48- .53	1.30-1.60	.40- .60	.40- .60	.....	.....
NE 52100A	.95-1.10	.25- .45	.20- .35	1.30-1.60	.35 max.	.08 max.
NE 52100B	.95-1.10	.25- .45	.20- .35	.90-1.15	.35 max.	.08 max.
NE 52100C	.95-1.10	.25- .45	.20- .35	.40- .60	.35 max.	.08 max.

* Recommended for large sections only.

Wartime Metallurgy Conserves Strategic Materials

Part VII—Heat-Treating Equipment

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Acme Steel Co., Chicago

PRECEDING articles in this series have dealt with the physical qualities and metallography of iron and steel as well as with the heat-treating operations needed to control these qualities. To give some idea of the limitations in obtaining the desired physical and metallurgical qualities, this article will consider the nature of the equipment used in heat-treating operations. There is an enormous variety of all types available and the applicability of any particular item depends upon a great number of variables of an economical and metallurgical nature. Such factors as the locality of the plant, the arrangement of equipment and the flow of work within the plant, the quantity being processed, the quality to be maintained, and so on, enter into this decision. So varied are these that they can be barely indicated. More detailed boks and papers are included in the references listed at the end of the article.

Open-fired furnaces, *Figs.* 56*a* and *f*, also *Figs.* 57*b* and *c* are used for all temperature ranges, but find their main field of application at the higher temperatures. They are commonly used for heating for forging, reheating of billets for rolling operations, and similar applications where temperatures are sufficiently high to be destructive to the metallic or refractory muffle furnace. They are also used in the lower temperature ranges where the application will permit of flame impingement with attendant surface scaling, local overheating and surface decarburization. The advantages of open-fired furnaces lie in a high heating rate and relatively high efficiency.

Semimuffle furnaces, *Fig* 56*b*, have the advantage of elevating the work so as to permit underfiring, giving a more uniform heating and protecting against the direct impingement of the flame. Heating is by radiation from walls and roof and by contact with the products of combustion. The scaling and decarburizatioin are lowered slightly, as is also the efficiency, from that of the open-fired furnace. A high heat type of this furnace, used for the heat treating of high speed steel, is shown in *Fig.* 58. Modern atmospheric control is impossible in these types of fuel-fired furnaces. The only control possible is by adjusting the air-gas ratio to a point where a "slightly" oxidizing atmosphere will be produced, resulting in a light scaling.

Full-muffle furnaces, *Figs.* 56*c* and 57*a* and *d*, are required for fuel-fired equipment when the nature of the parts being treated demands maximum protec-

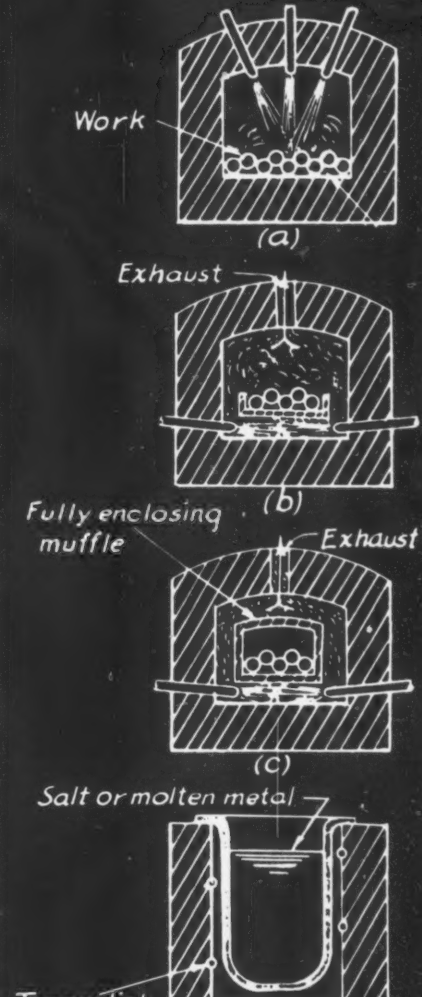
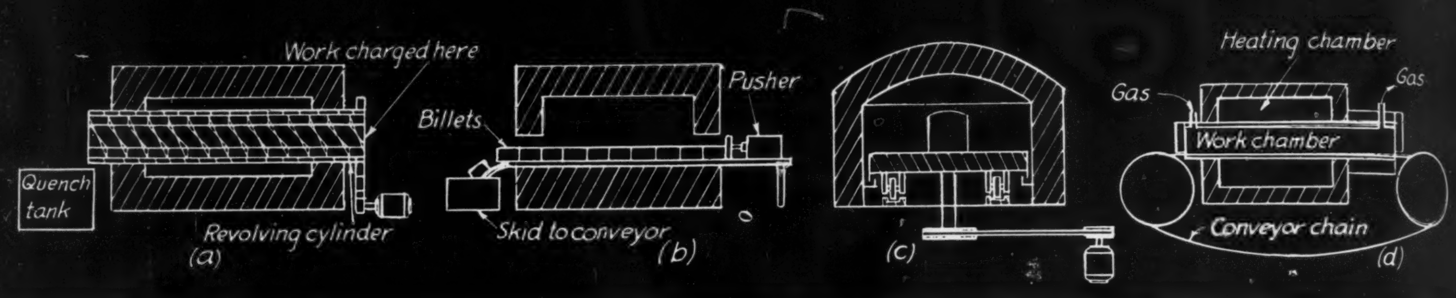


Fig. 56 — Batch handling furnaces: (a) open fired, (b) semimuffle, (c) full muffle, (d) pot type, (e) forced convection, (f) car bottom



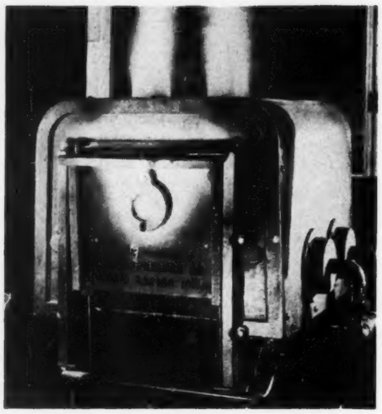


Fig. 57—Above—Various types of continuous furnaces: (a) screw conveyor, (b) continuous pusher, (c) rotary hearth, (d) chain conveyor with controlled atmosphere

Fig. 58 — Left — High-heat, semimuffle, gas furnace used to heat treat high-speed steel

tion against surface changes in composition. The muffle completely excludes the products of combustion, making possible control of the atmosphere in the work chamber by the introduction of externally prepared gases, or other similar means. Developments in fuel-fired bright heating (scaleless) have been confined to this type. Electric furnaces without muffles may also be used as there are no combustion products to contaminate the prepared atmosphere. Maximum operating temperature is limited by the material in the muffle. Higher grade heat-resisting alloys may be operated at temperatures of 1850 degrees to 2000 degrees Fahr. Refractories are employed at still higher temperatures. Pit type furnaces, *Fig.* 59, are muffle furnaces with the axis vertical.

The recirculating principle, *Fig.* 56*e*, has been applied to all types where it is necessary to depend on convection as the principle means of heat transfer, as is the case at the low temperatures of tempering furnaces. Rapid agitation of the atmosphere increases the rate of heat transfer and produces a uniform temperature distribution. Early furnaces were limited to a temperature of approximately 1250 degrees Fahr. because of limitations of material for the blowers. Present installations, however, are now being made at temperatures as high as 1700 degrees Fahr.

Pot type furnaces, *Figs.* 56*d* and 60, may be either fuel fired or electrically heated with the heat being applied between the furnace walls and the pot. They may, therefore, be classed as a special type of controlled atmosphere muffle furnace. The atmosphere is the molten material in the pot in which the work is immersed. They are used at temperatures ranging from 325 to 2400 degrees Fahr., depending upon the bath material and the construction of the furnace and pot. The low temperatures are used for the tempering of steel or heat treating of nonferrous materials, while the higher ones are used for hardening of high-speed steels. Intermediate temperatures are for hardening and surface carburizing.

Molten metals or salts are commonly used for the bath. Salts may also be used which decompose and envelop the immersed work in a gas film, designed either to prevent a change in surface chemistry or modify it as desired. These furnaces are most widely used in treating relatively small articles which may be placed in wire mesh baskets, as in *Fig.* 60, or hung from fixtures or wires. The heating rate is high, making them particularly desirable for local heating operations and high production. This high heating rate, however, leads to excessive warping or cracking of parts with irregular shapes and sections.

Large box type furnaces are used widely for annealing of large loads, such as strip steel coils, forgings and castings. The enclosing box and platform form a muffle which is then rolled into the furnace, as illustrated in *Fig.* 56*f*.

The radiant tube principle is a relatively new development which also finds application in large installations for the bright annealing of sheet, strip and wire in cut lengths or coils. It is being used also in large continuous bright-hardening operations. The burners are arranged to fire into heat-resisting alloy tubes, the products of combustion being carried to the flue, excluding them from the work chamber. Tubes are distributed along the furnace walls, heating being by radiation from the outside surface of the tubes. This principle has been used also in conjunction with prepared atmosphere and has frequently included recirculating equipment.

Conditions Determine Choice of Fuel

Most satisfactory sources of heat are natural gas, artificial gas, liquefied petroleum gases, fuel oils and electricity. Fuel oils are limited to the larger applications and higher temperature ranges such as reheating, forging and large annealing furnaces. Oil for smaller furnaces is usually considered inadvisable because of the storage tanks, pumps, strainers, heaters, etc., required, and because it does not lend itself as well to automatic control as does gas or electricity. Oil also does not give good combustion at lower temperatures. Commonly used gases are coke oven, natural, butane and propane. They are used for all temperatures employed in heat treating, ranging from a few hundred degrees to as high as 2400 degrees Fahr. Other advantages of the gases are the relative freedom from harmful impurities and the convenience of handling.

Electrical heating, while uncommon on large furnaces because of cost, is widely used for smaller units. Furnaces using metallic resistors of the nickel-chromium or nickel-iron-chromium type are limited to temperatures of 1850 to 2200 degrees Fahr. For higher temperatures, such as are employed for hardening high-speed steel, carbon or silicon-carbide resistors are used. Since electric furnaces have no combustion products even to protect the work partially from atmospheric air, controlled atmosphere is essential at temperatures over 1200 degrees Fahr., where heavy scale will begin to form.

Equipment for heating may be divided broadly into those for handling the work in batches, *Fig.* 56, and those for handling the work in a continuous flow, *Fig.* 57. Most furnaces are of the batch type, which may be accounted for by greater flexibility, simplicity of construction, and lower first cost and maintenance. Continuous furnaces employ a variety of methods for moving the material through the furnace. The most common are the pusher, *Fig.* 57*b*, rotary hearth, *Fig.* 57*c*, screw conveyor, *Fig.* 57*a*, and walker beams. Advantages of these furnaces are high production obtained by the continuous flow of material, and reduced handling.

Furnace atmospheres vary from direct exposure in untreated air to the many types of specially prepared atmospheres. Earliest attempts at control were by adjusting the fuel-to-air ratio of open and semimuffle furnaces. This method is still widely used and is satisfactory on products that will be subject to oxidation after removal from the furnace or that will be completely machined after treatment. If an attempt be made to eliminate scale completely by using a mixture rich in gas, decarburization will result. The best compromise is setting using a slight excess of air, producing a light free scale.

Probably the most satisfactory means of securing controlled atmosphere in open-fired furnaces is by packing the work with a protective compound. The parts are placed in suitable containers and covered with charcoal, cast-iron borings, spent carburizing compound, pitch coke, or proprietary annealing compounds. These serve to exclude the products of combustion and to generate gases which prevent scaling and minimize decarburization.

Electric or full-muffle fuel-fired furnaces permit the use of pack methods, or of specially prepared atmospheres. One type of full-muffle, batch-handling furnace generates its atmosphere in a separate heating unit by cracking a hydrocarbon oil and piping the generated gas to the heating chamber. This equipment is flexible as the gases may be adjusted readily to fit any analysis or temperature by controlling the quantity of oil delivered to the cracking unit. A simpler but somewhat less flexible type is illustrated in *Fig.* 61. In this furnace the hydrocarbon oil is cracked by dropping on a hot target placed inside the heating chamber. The atmospheres are, in each case, composed primarily of hydrogen and methane.

Fig. 59—Below—Pit type furnaces are used widely where controlled atmosphere is required for scale-free hardening

Fig. 60—Above—Salt bath pot furnace is, in effect, a controlled atmosphere muffle furnace. Small parts are handled in a wire mesh basket and dumped into the quenching media

Another generator principle involves the partial combustion of fuel in a special chamber employing a catalyst to support combustion of the rich gas-air mix. The resulting gas is then passed through refrigerators or driers to lower the water-vapor content. These units prevent scaling, though decarburization may occur at higher temperatures and on high carbon steels. This can be controlled by using other units to lower the carbon dioxide content of the gas.

A protective atmosphere of 25 per cent nitrogen and 75 per cent hydrogen may be obtained by cracking anhydrous ammonia by passing it through an electrically heated "dissociator." This gas can be adjusted to the temperature and to the steel being used by enriching with natural gas or other hydrocarbons.

Charcoal Gas Is Satisfactory for Low Temperatures

Charcoal gas generators also have been used successfully. Air is passed over charcoal heated to about 1800 degrees Fahr. The resulting gas contains about 25 to 30 per cent carbon monoxide, 1 to 3 per cent carbon dioxide, 1 to 3 per cent hydrogen and the balance nitrogen. Such a gas is suitable for annealing low carbon steel and for low temperatures but will decarburize higher carbon materials. This can be corrected by passing the gas through an absorbent to remove some of the carbon dioxide.

Other special atmospheres include natural gas or other hydrocarbon gases used for carburizing, dissociated ammonia for nitriding and mixtures used for simultaneous carburizing and cyaniding.

Quenching equipment is similar with only minor variations to fit it to special jobs. With this, as in the usual equipment, no special attempt is made to direct the coolant to a particular location on the work. Baths which continually receive hot material must be agitated by a circulating pump or other means, to prevent local overheating. The preferred operating range for aqueous solutions is about 70 to 100 degrees Fahr. and for oil about 90 to 140 degrees Fahr., although satisfaction may be obtained over considerably wider ranges.

Conveying mechanisms may be included when the material being quenched is uniform in size and shape. The metallurgical advantages are uniform duration of quench and agitation created by the movement of the parts. Such equipment is not practical when work of varying size is to be handled because of the constant changes in conveyor speeds that would be required.

Flush quenching, obtained by holding the work in special fixtures and spraying the coolant against the work, is frequently used to assure proper quench action in recesses, to avoid soft areas and in parts such as draw rings to create favorable hardening stresses. Palmer reports increases of the order of 115,000 pounds per square inch for flush-quenched cold header dies. The building of the necessary equipment is justified for jobs which are re-

current and which demand the special properties developed by actively quenching certain surfaces while perhaps retarding the quench on others.

Methods for observing, recording and controlling the temperatures of the heat-treating operations are as many and as varied as is the other heat-treating equipment. The most common practice is the use of thermocouples. These depend upon the fact that if an electric circuit is made up of two dissimilar materials, and the two junctions of the materials are at different temperatures, an electrical potential is developed in the circuit which may be observed in the deflection of a galvanometer needle. This potential is proportional to the temperature difference so that, by maintaining one junction at a constant reference temperature, (or by compensating for its variations) and placing the other in the furnace, the deflection of the galvanometer will be proportional to the furnace temperature, and may be accordingly calibrated. The galvanometer may also actuate a recording pen, tracing out the temperature on a suitably graduated chart.

On modern fuel fired furnaces, and in particular on electrically heated units, the galvanometer is frequently arranged to trip preset limiting devices which actuate valves or switches. With this control the work may be heated at a selected rate and held at a predetermined temperature until ready for quenching.

For rolling and forging operations and in many high heat furnaces where a thermocouple may not very well be employed, or where the temperatures are too high for their satisfactory use, optical and radiation pyrometers are commonly used. The first depends upon the fact that the light emitted from a heated body depends upon its temperature. The work is viewed through a suitable low-power telescope and the color of a filament of wire placed in the field of vision blended to that of the work by varying the temperature of the filament. The temperature of this standard filament is then obtained by measuring the current required to heat it. A chart attached to the variable resistor in the filament circuit may be graduated in temperature degrees if a calibrated electrical potential is employed. This is obtained by balancing against a standard Weston cell.

Fig. 61—Electrically heated pit type batch furnace with recirculating atmosphere. Hydrocarbon oil is cracked on hot target inside furnace to generate protective gases

Radiation pyrometers are most common at the very high temperatures, such as in melting and steel-making operations. They depend for their operation upon the energy radiation emitted by a hot body.

Special Equipment Facilitates Production

The above illustrates some of the more common types of heat-treating equipment. In addition there is an enormous variety of specialized equipment, such as high-frequency induction heaters, resistance heaters, flame hardening apparatus, etc. The three methods specifically mentioned are of such importance that a brief discussion of each will be given.

High-frequency heating is accomplished by passing a high-frequency current through an inductor block which surrounds, but does not touch, the article to be hardened. This current produces a strong magnetic field which cuts the surface of the part through an air gap, and induces eddy currents in the surface. The magnetic field also creates hysteresis losses. The combined eddy current and hysteresis losses cause heat to be generated in the surface of the steel itself. Quenching is accomplished by a water spray directed on the heated surface through holes in the inductor block. This process was brought to a high state of development by The Ohio Crankshaft Co. for the surface hardening of crankshaft bearings. It is now being applied to numerous cylindrical and tubular parts, as well as parts of more complicated shape, on which localized heating is desired. This principle is also being used successfully in brazing and soldering operations. Confinement of the heated area to specific portions permits brazing of heat-treated assemblies without affecting their physical properties.

The advantages of induction heating are an extremely high heating rate, negligible scaling or decarburization, accurate control of depth, width and location of the heated areas and less distortion than encountered when conventional hardening methods are employed. Another advantage of particular significance today is the ability to produce high surface hardness on large articles without the use of critical alloys.

Another method of localized heating, commonly referred to as flame hardening or flame annealing, is accomplished by applying a high temperature gas flame to the surface to be treated. When hardening is desired the flame is immediately followed by a water spray. Fuels most commonly used are acetylene and oxygen, although special burners have been developed which employ domestic gas and atmospheric air. Ordinary hand-operated torches may be used but more uniform results are obtainable with mechanized equipment and special torches developed to

fit each application. Flame hardening is probably most widely used on the teeth of large gears. In this application the torch progresses along the tooth face and is followed by a water spray. Depth of hardened case is accurately controlled by the setting of the torches and the rate of traverse.

Other applications include the hardening of machine tool ways, rail ends, crankshafts, camshafts and a large variety of cylindrical or tubular parts. *Fig.* 63 illustrates a machine which was developed for automatic flame hardening of a high production part that was to be locally hardened over a small region. The six-station wheel indexes at regular intervals, carrying the piece from the heating flame to the quench below. Flame intensity and timing are adjusted to produce the proper case depth and hardness.

The advantages mentioned for induction heating apply also to flame heating, although it is somewhat easier to obtain uniform results from lot to lot with induction equipment. Flame heating equipment, however, is more readily adapted to parts of irregular shape, and can be used on some parts where induction heating cannot be accomplished.

Fig. 62—Induction hardening equipment for treating the teeth on drive sprockets for military tractors

Heating is accomplished in resistance heating equipment by passing the current through the part to be heated. Control is obtained by using the expansion of the metal between the contacts to actuate current-regulating devices or by using radiation pyrometers. This process differs from the two mentioned above in that the heat is applied throughout the cross section and is not confined to the surface. For this reason, in surface hardening, it requires more energy than the flame or induction method. This method finds its largest field of application in through-hardening operations requiring extremely accurate control and in local heating for forging. It is also used for strand annealing and heat treating of wire, and for stress relieving or complete annealing of copper rods, tubes and shapes.

The next article will discuss the variety of elements that distinguish commercial carbon steel from an alloy of iron and carbon, the "assisting" elements, manganese and silicon, the usually deleterious elements sulphur and phosphorus, the killing of steel with aluminum and the effect of its oxides.

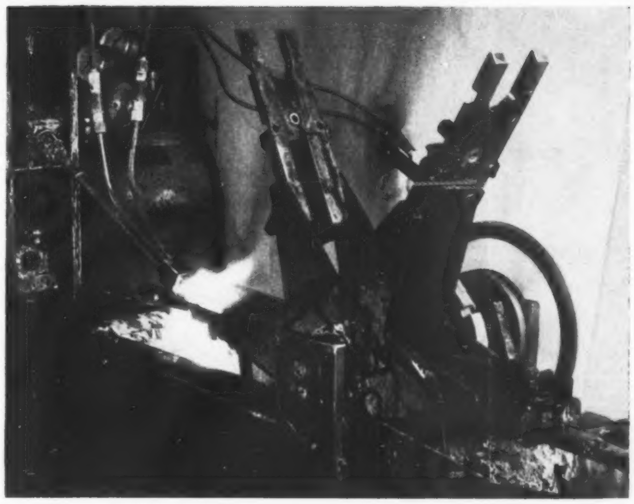


Fig. 63—Automatic flame hardening equipment for local hardening of small parts. Wheel carrying work indexes forward, timing the heating and quenching cycle

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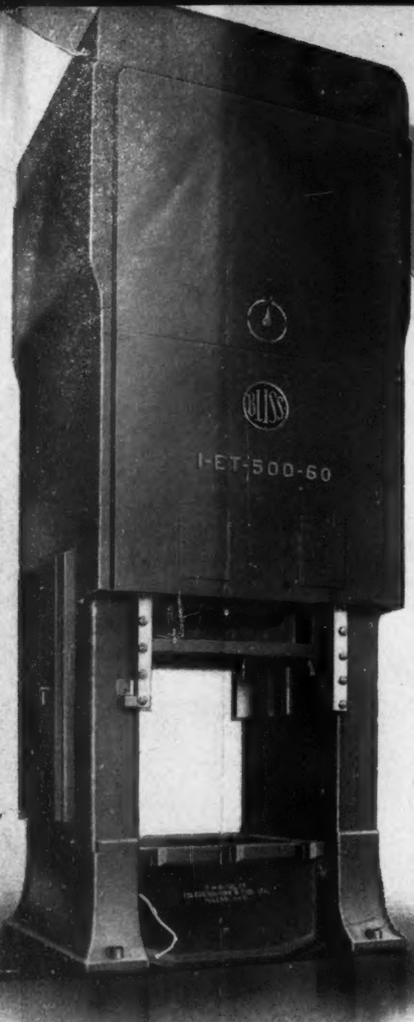
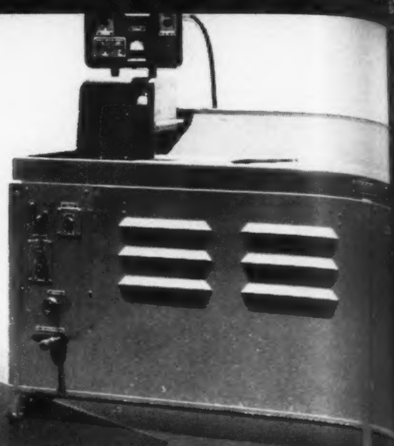




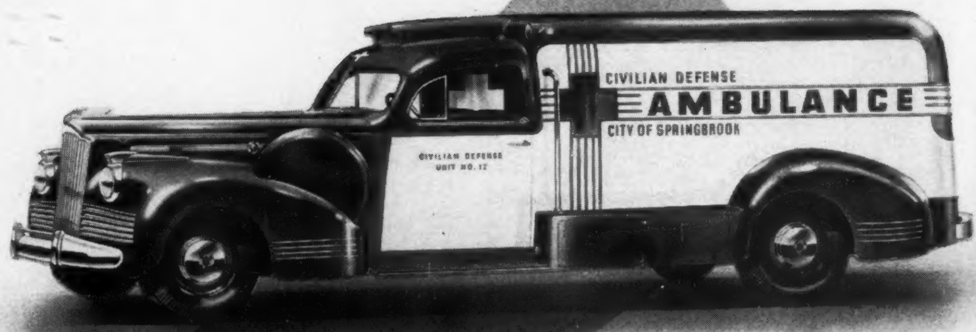
Right—Using an integrally mounted bipolar coil, the Western Industrial magnetic inspection machine includes a cabinet into which surplus ferrous oxide solution drains. Cam action clamp on tailstock allows use of a cover. To conserve scarce materials light-gage pressed steel is used in place of aluminum for the covers and instrument box

Left—Frame of the Bliss one-point double-action toggle drawing press consists of base, two uprights and a crown held together by four steel tie rods, shrunk into place. Removal of three light covers permits inspection and adjustment of enclosed working parts, including flywheels and gears. Machine is designed for easy conversion to single action or triple action

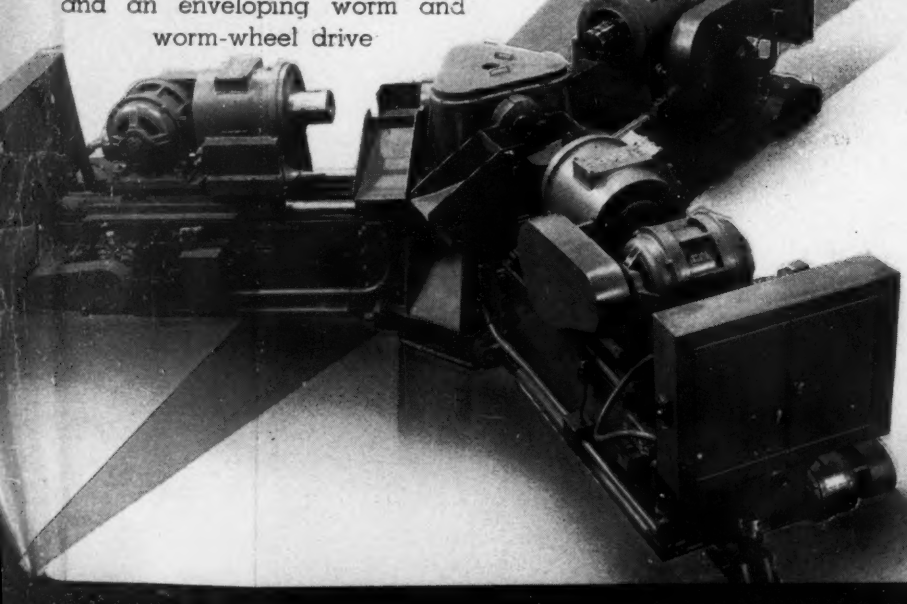
Machine B
the Gun

(For new machin... see page

Right—Pendulum type stretcher support enables inexperienced helpers to load patients into the Henney ambulance. Four stretcher patients, four attendants, and all necessary first aid equipment and tools necessary in a bombed area can be carried



Below — Primarily designed to speed production of aviation propeller hubs, the Baker three-way horizontal-feed driller uses welded construction for the three frames and center bed. Each spindle is driven through a train of flame hardened helical gears and an enveloping worm and worm-wheel drive



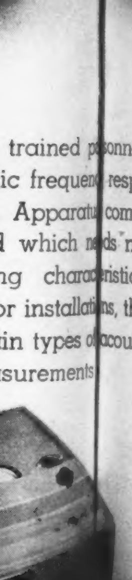
Below—Releasing electrically trained personnel f other war duties, the automatic frequency respon recorder made by the Sound Apparatus compan produces a permanent record which needs no plotting. Besides determining characteristics audio apparatus components or installations, the strument can be used for certain types of acoustic and vibration measurements

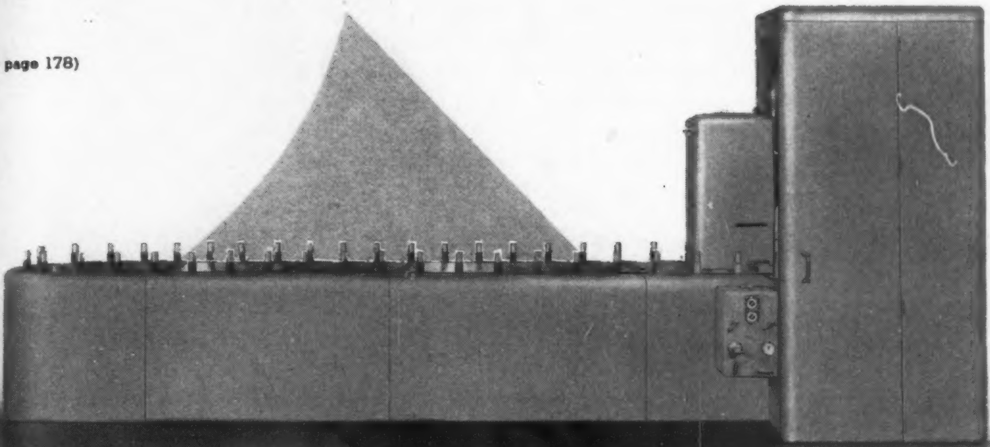
Right—Combining the functions of a horizontal boring mill and a jig borer, the De Vlieg Jigmil includes automatic table retraction and repositioning. The 3-inch nitralloy bar is provided with power feed and rapid traverse in both directions. Five independent motors furnish power for main spindle drive, bar rapid traverse, bar feed, table rapid traverse, and automatic positioning

nine Behind he Guns

(For new machin... see page 178)

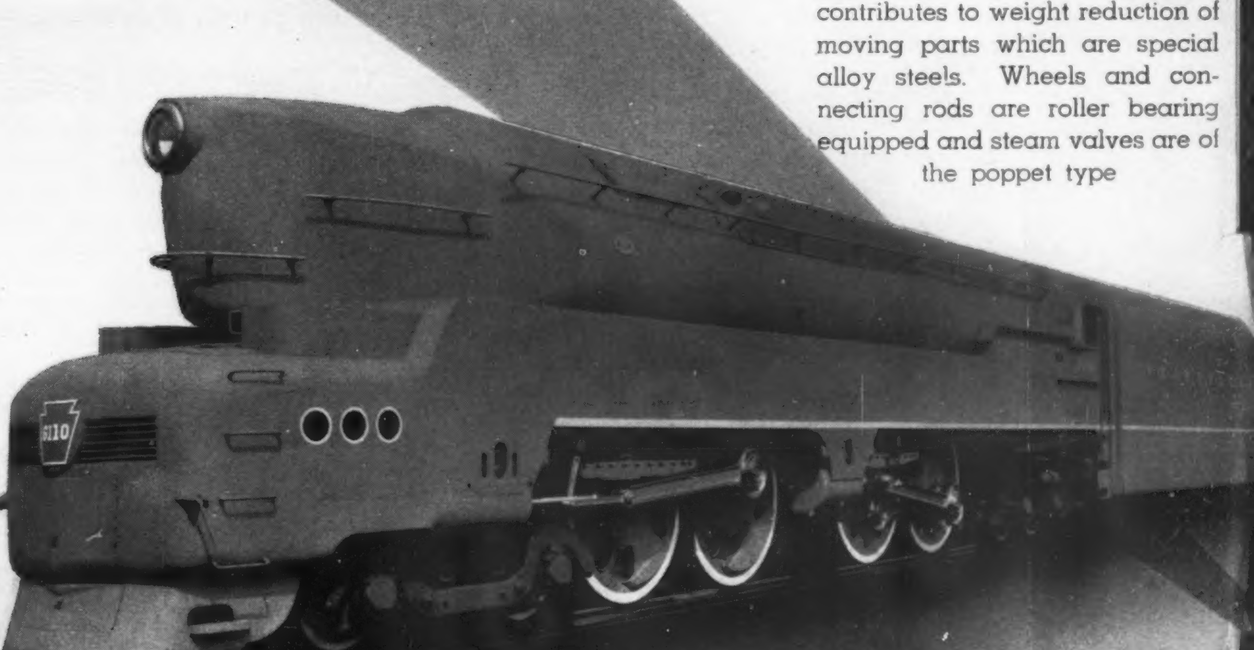
trained p...onnel for ...ic frequen... response ... Apparatu... company ...d which n...ds no re-...ng chara...ristics of ...or installati...s, the in-...tin types o... acoustical ...surements





Left—Ammunition of all kinds in a variety of sizes is automatically painted in the new DeVilbiss shell coating machine. Designed for maximum operating speed consistent with uniform surface finish, the machine sprays inside and outside surfaces, the spray guns being actuated only when each shell moves on the conveyor within spraying range

Below—Speeding the movement of armed forces and civilian leaders, this Baldwin-built locomotive hauls an 880-ton train at 100 miles per hour. Use of four cylinders contributes to weight reduction of moving parts which are special alloy steels. Wheels and connecting rods are roller bearing equipped and steam valves are of the poppet type



Fewer Models—Greater Production

CONTROVERSY will be rampant, from this stage of the war on, as to the advantages of simplification in design, i.e., few models of each type of equipment, as against the development of many new models. At the moment, simplification seems to be winning out.

One of the primary reasons for this undoubtedly is the difficulty, due to increased Axis submarine activity, of transporting arms to the battle fronts. If only a percentage of total shipments is reaching its destination the pressing need is for increased production rather than new models—at least until such time as antisubmarine warfare becomes more successful.

Designs necessarily must be stabilized for certain periods to facilitate peaks of production; at other times the emphasis rightly can be placed on new models. Bearing upon this is a recent remark by Major General L. H. Campbell, Jr., chief of ordnance services of supply: "If the war lasts but a few years, what we consider now as 'top flight' may well be obsolete at the end of that time . . . Therefore we must and will continue in research and development."

If such research and development could be directed toward not only the creation of new models but also toward limiting the eventual number of each, armament production would more quickly gain and hold its essential momentum.

Wartime Restrictions

IT will come as no surprise to readers of MACHINE DESIGN *to hear that government limitations have been placed on the use of paper by magazines, including technical journals. Shortage of manpower and the consequent inability to maintain production on the previous level is primarily responsible for the order.*

Though no immediate effect will be apparent in this issue of MACHINE DESIGN, *due to paper stock on hand, the "trim" size of future issues will be reduced considerably, giving narrower margins around the printed matter. Slightly smaller type will be employed in certain regular departments of the magazine and to conserve metal fewer illustrative cuts will be used.*

Other modifications unquestionably will prove necessary, but the editors are confident that MACHINE DESIGN'S *readers will accept these gladly in the full knowledge that editorial standards will be maintained.*

L. E. Jermy

Effect of Nut Design on Strength of Threaded Fastenings

BASED on a recent A.S.M.E. paper by M. Hetenyi, research engineer with Westinghouse, this data sheet presents results of an investigation of the stresses in threaded connections using different nut designs. The test procedure, which is described in the original paper, involved the three-dimensional "stress-freezing" photoelastic method

DIMENSIONS of bolt models with six different nut designs are shown on the following page, together with a graphical representation of stress data derived from photoelastic pictures. In each specimen the maximum stress value observed at the bottom of the threads is referred to the average stress in the full body of the bolt, thus defining for each thread a concentration factor k. The figure shows how these k values vary on the right and left side of the slice in each particular nut design. Maximum concentration of stress is found in the conventional nut type ($k = 3.85$) above the thread nearest to the bottom of the nut. However, when the position of the nut is such that the first thread in the section of the slice is only half engaged and thus provides a more resilient support, the place of the maximum stress usually shifts to the base of the second thread from the bottom.

It is seen from the figure that nuts with outer support, spherical washer, or double thread, give approximately the same stress-distribution curve as the conventional nut type and therefore cannot be considered as improvements. Only the last two nut designs, namely, those with tapered thread ($k = 3.10$) and tapered lip ($k = 3.00$) show a definite improvement in the stress distribution. In the model with tapered threads the stress distribution could probably be further improved by applying a still larger taper in the nut.

The design with a tapered lip gives the greatest reduction of peak stress among all the six nut designs. Since the fundamental cause of stress concentration is the differential strain between bolt and nut, one of which is in tension and the other in compression, the application of a lip which is in tension like the bolt itself is naturally an effective way of easing up the transmission of the load from bolt to nut. As is shown in the figure, the peak stress values could probably be somewhat more reduced by applying a greater tapering of the lip which would decrease the amount of load carried by the first few threads and would transmit more of the load to the upper part of the bolt.

The results show that the maximum fillet stress value occurring in a conventional nut and bolt fastening can be reduced by about 30 per cent through the application of nuts with either tapered threads or tapered lips. It appears probable that by the use of either larger tapering or longer lips than those tested and already referred to, the reduction of stress could be increased up to 40 per cent. In this latter case, however, the maximum stress in the fastening would already be lowered almost to the notch stress value of the threaded bolt body itself, which puts a natural limit to the strength of the whole threaded connection. Though in the present tests Whitworth threads were used in all samples, it is believed that comparative strength of the foregoing nut designs would be in about the same ratio for other types of threads.

While the tapered lip design shows in these tests approximately the same strength as the one with tapered threads, each of these designs has some characteristic features which should be considered in their application.

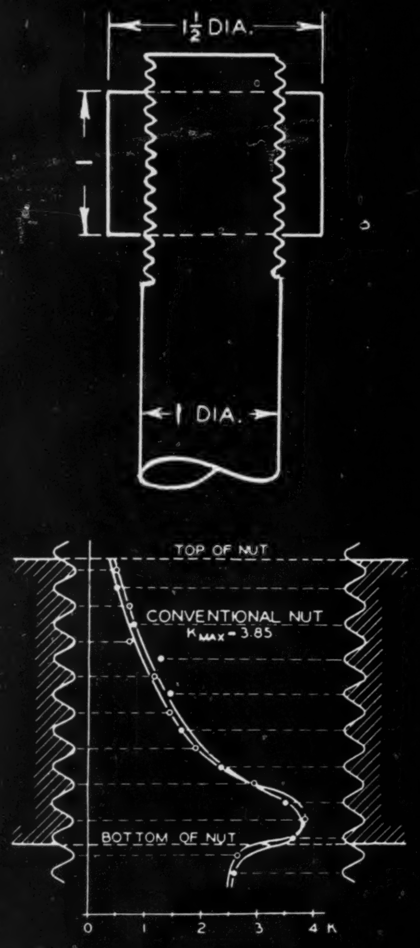
Tapering of the threads in the nut aims to compensate for the difference in strain between bolt and nut and needs, therefore, very accurate machining. Since one definite value for the tapering will correspond to a certain amount of strain, the best results with a taper-threaded nut are obtained only at a particular value of the load on the bolt, at which the bottom threads are barely in contact. Under such circumstances the taper-threaded nut gives about the greatest strength obtainable with any fastening. As soon as the stretching of the bolt, owing either to loads or to creep or relaxation, brings the bottom threads in contact, the nut will begin to act as one of the conventional design, transmitting an increasing amount of load to the bottom threads.

Tapered Lip Effective at Any Load

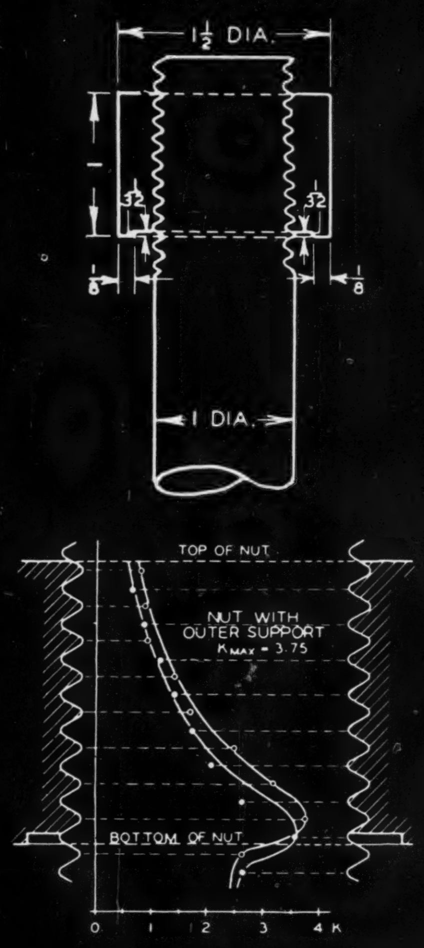
The effectiveness of the tapered-lip design, on the other hand, will be about the same for any value of the load. The lip is always in tension like the bolt itself and will fill the gap between the tensile and compressive strains of the bolt and the nut respectively. In this case the greater the stretching in the body of the bolt, the larger portion of the load will be transmitted through the upper part of the nut which will be in any case stiffer than the tapered lips. The only problem in applying this type of nut seems to be in providing for it a proper support under the flanges. This can be accomplished by either countersinking the lip part into the bolt hole or by supporting the flanges on washers which would accommodate the lip part.

Since the comparative strength of the above nut designs have been derived from tests made under purely elastic conditions, the applications of the results will also have to be limited to cases where somewhat similar conditions prevail. The improved nut design, for instance, would hardly increase the strength of bolts under static loads at normal temperatures since in such cases, usually, yielding in the threads produces a stress distribution radically different from the ones obtained above. On the other hand, whenever the conditions of the loading are such as to cause the threaded part to fail without any appreciable deformation, the application of the above results seems to be justified. At present the two main fields of application appear to be dynamic loads and static loads at elevated temperature (causing embrittlement). In both of these cases an increase of strength of about 30 per cent can be expected through the application of either of the two improved nut designs.

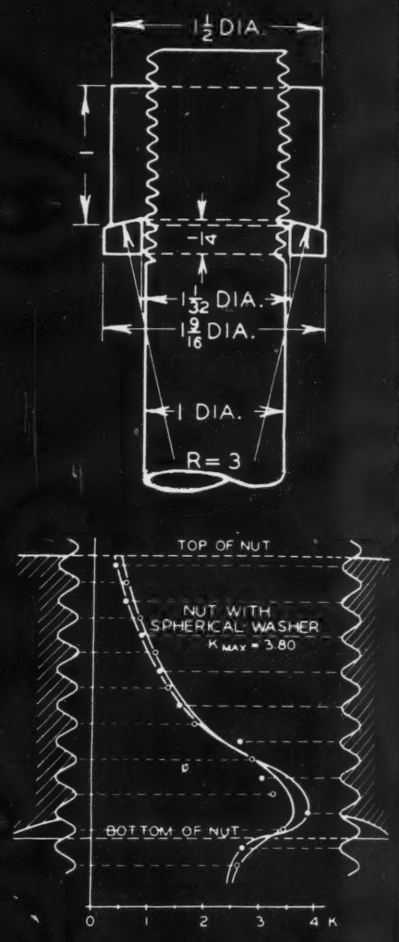
CONVENTIONAL NUT



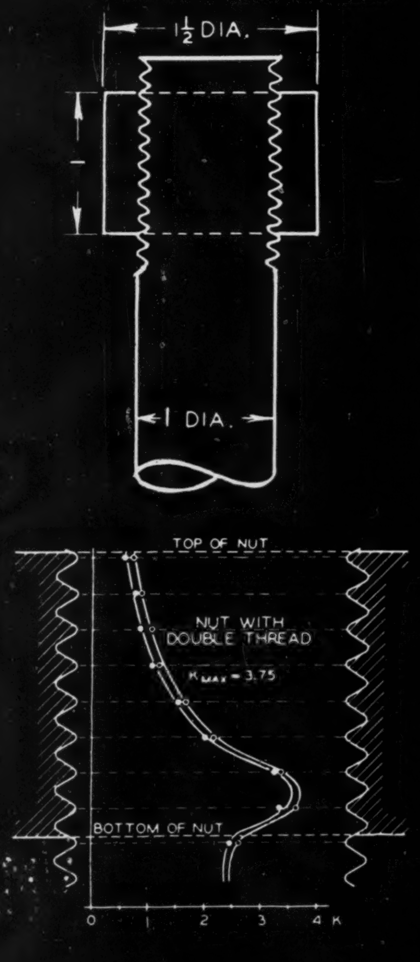
NUT WITH OUTER SUPPORT



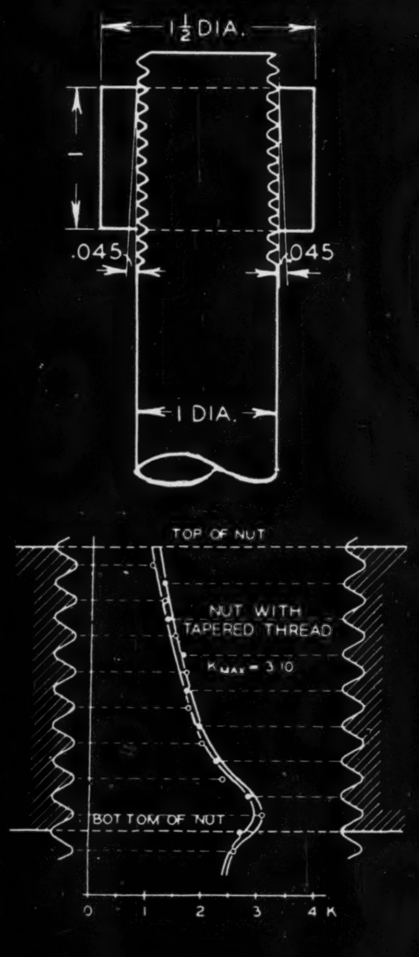
NUT WITH SPHERICAL WASHER



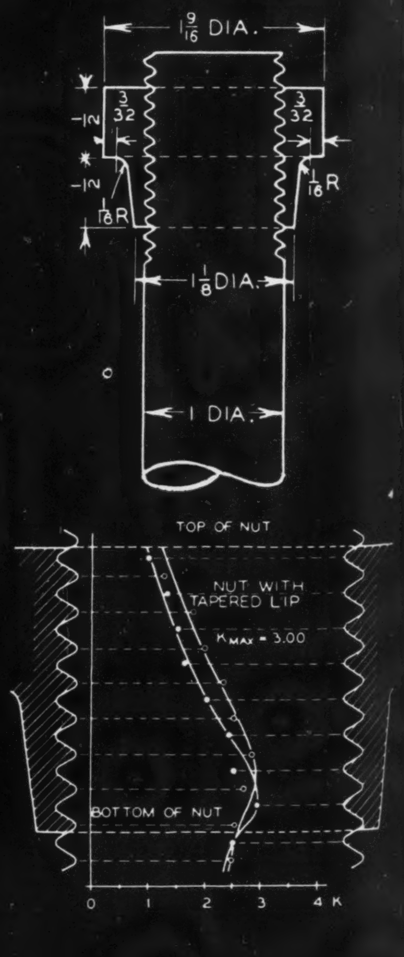
NUT WITH DOUBLE THREAD



NUT WITH TAPERED THREAD



NUT WITH TAPERED LIP



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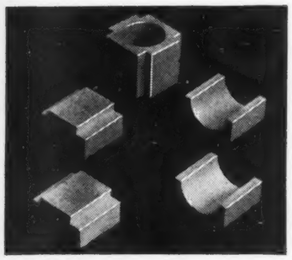

Ledaloyl is ideal for odd or intricate shapes, as it eliminates all machining . . . provides self-lubrication Write for new literature.

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Johnson LEDALOYL Bearing Bronze is the newest development in powder metallurgy. Our patented process, using pre-cast bearing bronze, enables us to definitely control the structure of the bearing or part. This provides uniform strength and uniform, dependable lubrication. Why not consider the use of LEDALOYL in your new product? A Johnson engineer will gladly show you how . . . and where. He will base his recommendations on facts . . . free from prejudice . . . without obligation. Call him in today. Johnson Bronze Company, 525 South Mill St., New Castle, Pa.

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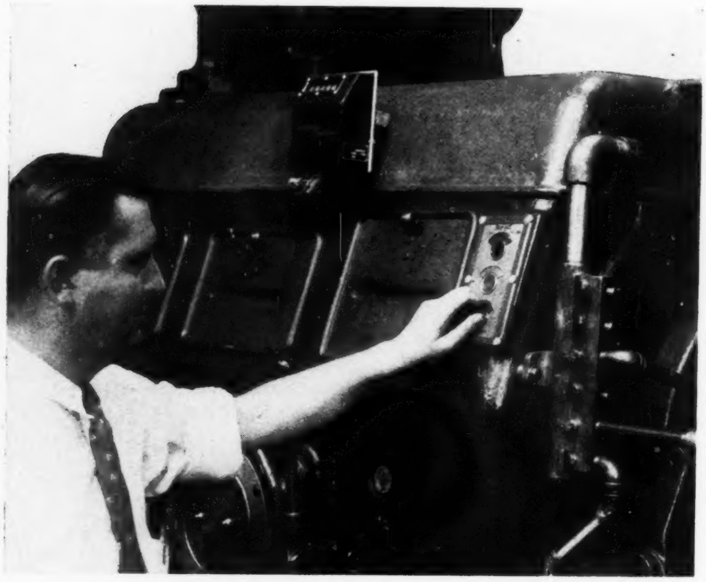
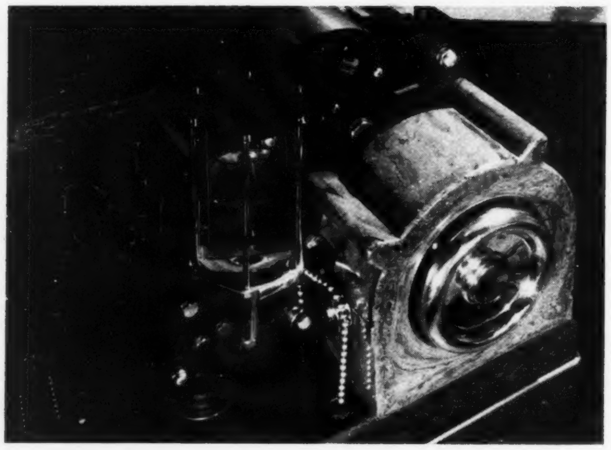
Applications

of Engineering Parts and Materials



Switch Action Reduces Arcing

THREE button flush type Snap-Lock control station switch is used on the Acme-Gridley automatic shown at left. Switch case is molded dielectric plastic with gasketed cover, while the push button mechanism passes through the mechanical side only, eliminating danger of shock to the operator from a flashback. Switch is single pole, double break, double throw with self-wiping coin silver contacts, while mechanical parts are hardened steel cadmium-coated. Spring pressure insures snap action and positive locking in either position, reducing to a minimum the possibility of arcing, one of the commonest causes of control station switch deterioration and failure. Basic units can be arranged in combinations to produce control station assemblies for handling a wide variety of functions.

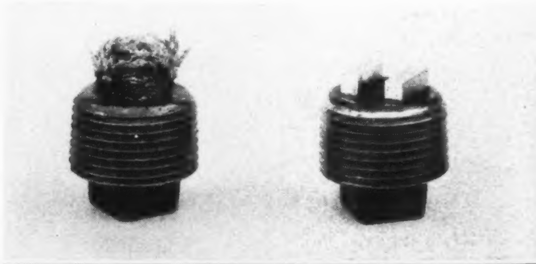


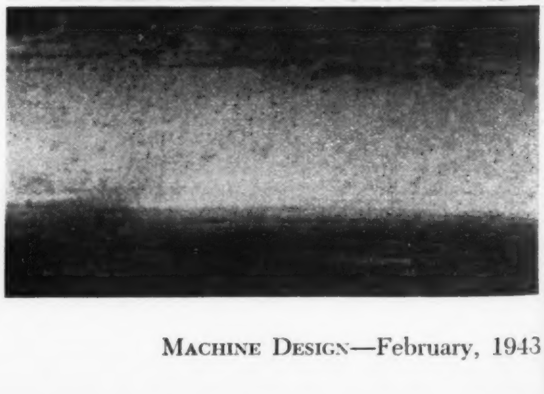
Office Machine Uses Cast Resin Guard

BELT guard on the Standard Mailing Machines Co. duplicating machine shown at left is Catalin cast resin. Use of this thermosetting resin enabled the manufacturer to get into production promptly and because the number of parts molded was small, the relatively low cost of tools for the production of castings was economically amortized. Electrical and mechanical grade used for the part shown has a tensile strength 8500 to 10,000 pounds per square inch. Material is ordinarily furnished as cured castings in a variety of standard shapes such as sheets, rods and tubes, which are readily machined to finished parts.

Drain Plugs Trap Ferrous Particles

ENTRY of foreign matter into the housing is a predominating factor causing premature failure of antifriction bearings. Because the internal clearance between the rolling elements and the raceways is held to such close limits, particles small enough to pass through an ordinary screen may cause severe overload stresses when interposed between the contact surfaces. Effect of the resulting action on the raceway is shown at lower right. Lisle magnetic drain plugs, upper right, which attract ferrous particles circulating in the lubricant, are saving bearing wear on airplane engines, speed reducers, machine tools, road machinery, trucks and busses, and many other types of machines. The unusually large accumulation of iron and steel particles on one of the plugs was removed from a gear housing after a 24-hour test run.





New PARTS AND MATERIALS

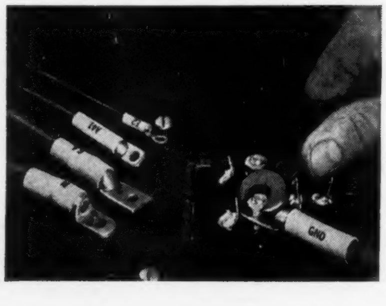
Coolant Pumps Are Self-Priming

FOOT-MOUNTED, self-priming centrifugal coolant pumps introduced by Brady-Penrod Inc., 1216 West Second street, Muncie, Ind., are ready for immediate delivery. The pump, known as Model SP-400, is simple in design and primes almost instantly on normal machine tool suction lifts. It also reprimes if the sump pump runs dry, as soon as it is refilled. Sturdily built to withstand long service, the pump will handle

abrasives and steel chips. Flow of coolant is controlled by a valve at the discharge line, from a few drops per minute to full capacity of the pump, without overloading the motor. Two models of the pump are available—one of 8 gallons per minute capacity, and the other of 20 gallons per minute. On pumps with capacities up to 100 gallons per minute and special current specifications, information can be obtained from the company.

Combination Insulating Tubing

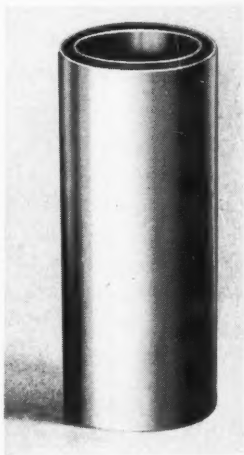
TO PERFORM two jobs, Irvington Varnish & Insulator Co., 6 Argyle Terrace, Irvington, N. J., has introduced its short lengths of extruded plastic tubing, clearly marked with letters and numerals. They serve as insulators of terminal



connections and as wire markers. Where lug insulation and wire identification are required, assembly is speeded by eliminating any additional means of identification. The tubing has a very high dielectric strength, and a smooth inside surface to permit quick application over wires and lugs. Legible numerals of the customer's choice are printed on the tubing with an ink that is resistant to chemicals, water and oils. The tubing is available in colors, with either black or yellow symbols, in A.S.T.M. sizes from No. 9 up to ⅜-inch inside diameter.

Bushing Is Rubber-Insulated

CAPABLE of absorbing vibration and shock and of taking torsional and radial movement without lubrication, a new line of rubber insulated bushings is now being manufactured by Bushings Inc., 3447 West Eleven Mile avenue, Berkely, Mich. A saving of 60 to 80 per cent in rubber in one application has been made, and from 10 to 20 per cent of the amount usually required for bushings of the conventional design without reduction of efficiency or life. Manufactured for armed combat equipment, the bushings are available in a wide range of sizes. Known as Rubberflex, they employ a thin layer of live rubber (or synthetics) held between an inner and outer cylinder of metal entirely by the elasticity of the rubber itself, making a mechanical and slip-proof bond for high torsional angles.



Simplicity of the bushings permits a wide range of sizes and capacities to suit individual requirements. When the assembly is completed, the force of the elasticity of the rubber in both directions keeps it together. Wear in the bushings is absent since torsional and radial movement is taken in the rubber itself. Thus with no lubrication required, the bushings provide for motion of adjacent parts even under operating conditions where they are entirely covered with sand, mud or dirt.

Small Motors Are Air-Driven

SMALL air-driven, double-acting, reciprocating motors have recently been introduced by Smith-Johnson Corp., Bendix building, Los Angeles, for operating on any air pressure up to 175 pounds gage. The motors employ a special integral valve for controlling their piston action. They are specifically designed for use as auxiliary power units on larger machine tools or as independent prime movers on small fractional horsepower units. Model AM Senacon motor has a standardized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ALUMINUM CASTINGS
Photograph shows a load of castings ready for heat treatment . . . Note size of castings in comparison with man at left.
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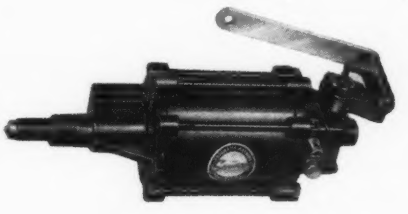
piston diameter of 2.5 inches. It develops a piston thrust approximately 4.9 times the operating air pressure, and a piston pull approximately 4.6 times the operating air pressure. Furnished in standard piston strokes of 1.5, 2.5, 6.0 and 9.0 inches, it may be obtained in special stroke lengths from 1.0 to 18.0



inches. The integral air valve of the motor is designed to effect ready synchronization of the movement with the main operation. Its universally adjustable lever permits operating the valve from any angle in any plane by a drag link connection off a convenient reciprocating element of the machine. Dual exhaust ports provide for selective utilization of the exhaust air blasts for many special control operations.

Speed Control Units Available

NEW speed control units are being made by Smith Power Transmission Co., 1545 East Twenty-third street, Cleveland, for incorporation into machine tools. Of sturdy construction the control can be mounted horizontally or vertically. Gears, which slide on heat-treated splined shafts, are of

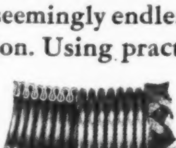
hardened and shaved alloy steel, and run in a sealed case filled with oil. With a single handwheel control, the unit is available as standard stock in both four and eight-speed models, or can be manufactured to meet customer's specifications.

Chemurgic Synthetic Rubber

AVAILABLE commercially now from Reichhold Chemicals Inc., 601 Woodward Heights boulevard, Detroit, is a chemurgic synthetic rubber, Agripol, a satisfactory substitute for natural rubber in many applications of a mechanical nature. The mechanical parts referred to include gaskets, belting, insulating mats, hose linings, etc. For military uses, Agripol is used for insulating parts, shock absorption pads, gaskets, etc., in aircraft, naval and cargo vessels, motorized military vehicles and weapons. Where high tensile strength and resistance to severe abrasion are desirable properties, Agri-

To convey gas, oil, air and water, as well . . .

Perhaps the most intriguing angle of flexible metal hose and tubing is its seemingly endless range of application. Using practically any workable metal, we can build flexible hose or tubing for anything from a simple spout to a high pressure seamless hydraulic line that can be flexed millions of times without breaking—a line that will give you the flexibility of garden hose, the dependability of metal and the *strength of rigid pipe!*



American Seamless — corrugated from seamless rigid tubing . . . no welds, laps or joints . . . made in several alloys.

Whether you need a flexible connector for misaligned or moving parts, for isolating vibration, for conveying air, water, oil, steam or fuel, you'll likely find we have a type of flexible metal hose or tubing that will do the job more capably.

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American Metal Hose

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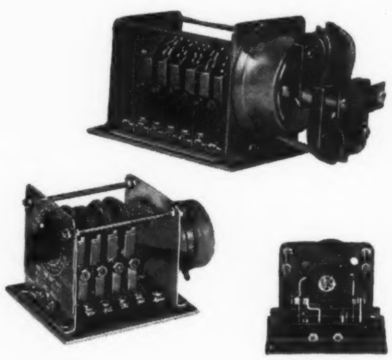
pol is inferior to natural rubber. However, for molded parts for static use, high tensile strength and great elongation are not essential and Agripol may be used. In aging tests this material is less susceptible to attack by elements and in resistance to oxidation it surpasses natural rubber.

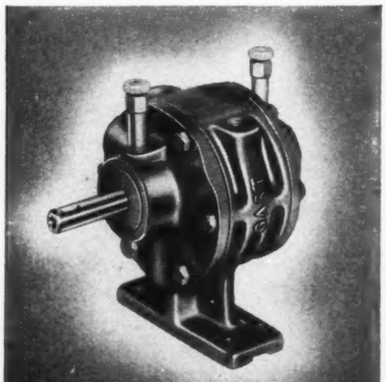
Multicontact Timer Announced

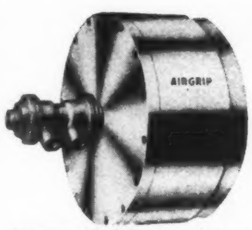
MULTICONTACT timers to control automatically a sequence of "on" and "off" operations of a single or a multiple number of electrical circuits in accordance with a predetermined operating program, have been announced by The R. W. Cramer Co. Inc., Centerbrook, Conn. Features of the new timer, known as the Type MC-2, 2-minute, 2-circuit timer, are: Self-starting synchronous motor, complete gear trains operating in oil, bakelite cams mounted on shaft in identical pairs to permit the "off" and "on" increments to be adjusted to the desired operating program. Contacts are in plain view so that operations can be observed. The timer can also be provided with remote momentary starter. A special multicontact timer gives various timing impulses every 1, 2, 3, 4 and 5 seconds, and for circuit No. 6 the timing impulse is at 1-minute intervals.



Rotary Air Motor Developed

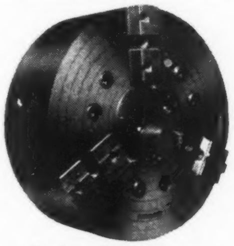
SUITABLE for locations where compressed air is available and where explosionproof equipment is essential, the rotary air motor announced by Gast Mfg. Corp., Benton Harbor, Mich., is obtainable for new applications. It is particularly applicable to war-production jobs such as driving mixing equipment for munitions plants, etc. Offering a variable





Anker-Holth revolving air cylinder

Anker-Holth air operated collet chuck



Anker-Holth air operated, three jaw, universal chuck

When You Equip Lathes, Vertical Millers, and Drilling Machines with "Airgrip" Chucking Devices.

MANY of America's leading aircraft engine and parts plants are using Anker-Holth air-operated chucking devices to speed output—to help planes fly away faster to the battle fronts.

If you are an engine or parts manufacturer we urge you to investigate the use of "AIRGRIP" cylinders, chucks, and other air-operated and hydraulic devices, which consistently result in *stepping up production 25% or more.*

Our engineers are ready to help you in the selection and installation of air operated chucking devices on new machines now on order, or on machines now operating in your plant. Our deliveries are extremely favorable for prompt action. Send in your piece part prints. Act today!

WRITE FOR NEW CATALOG

Anker-Holth Mfg. Co.

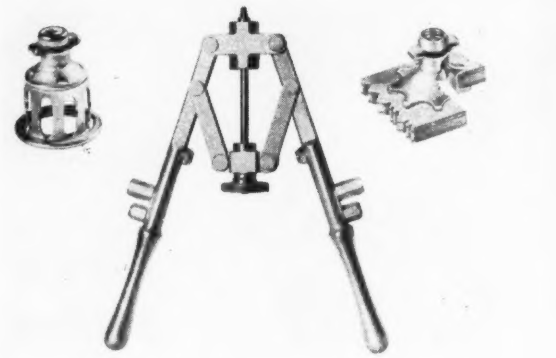
"AIRGRIP" CHUCK DIVISION

332 So. MICHIGAN AVE. • CHICAGO, ILL.

speed over a wide range, the motor employs the same rotary principle as the company's pumps and compressors. It contains no reciprocating parts or springs. Delivering from 1/20 to 1 horsepower, the motors are fitted with ball bearings and all parts are accurately ground. Self-adjusting shaft seals are used in place of packing.

Speed Nuts for Plywood Use

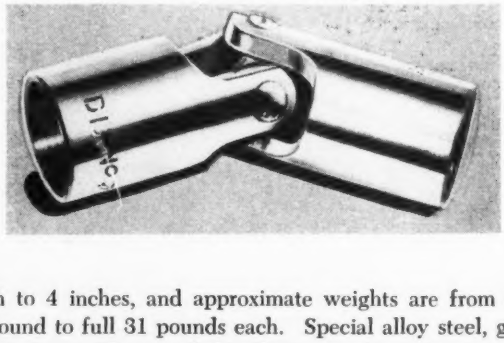
DESIGNED to speed production and subassemblies in plywood aircraft, a new self-locking "cage" nut has been offered by Boots Aircraft Nut Corp., Main street, New Canaan, Conn. The "cage" nut, so called because of its bird-cage design, is used to fasten metal to wood. It incorporates the wing style, all-metal, self-locking principle and



may be applied, if necessary, in a blind application from one side. The basket mount of the nut is "collapsed" with the special clinching tool. The collapsed mount then clinches the plywood in a claw-like grip which withstands, without tearing, the torque applied when a bolt is inserted by production methods. The nut is adjustable to varying thicknesses by the use of stop arrangements. The clinching tool sets the mount into the plywood or plastic in thicknesses of 1/16-inch and up.

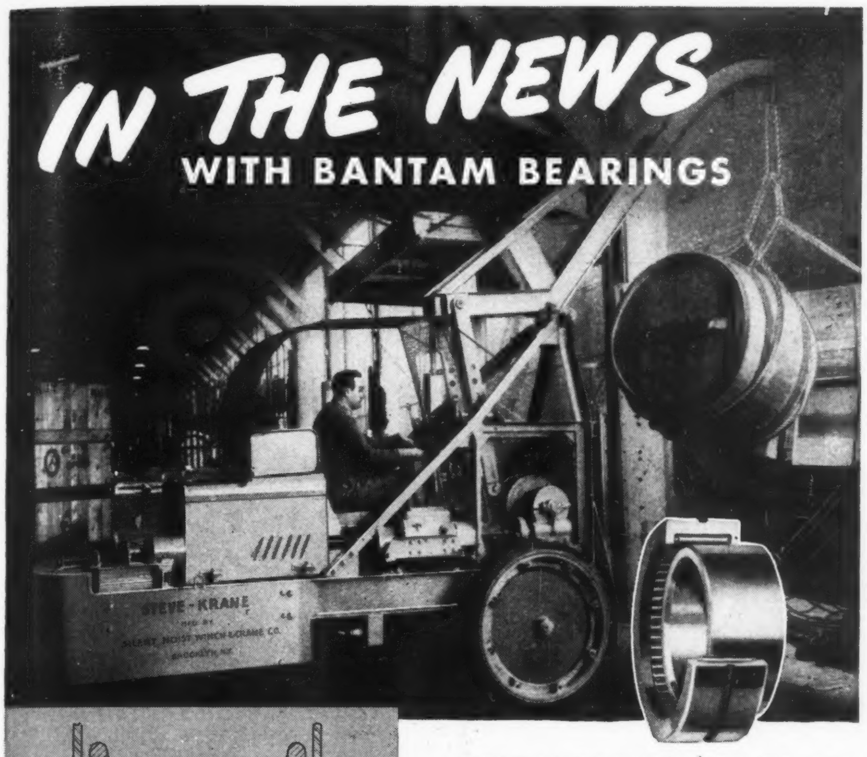
Aircraft Type Universal Joint

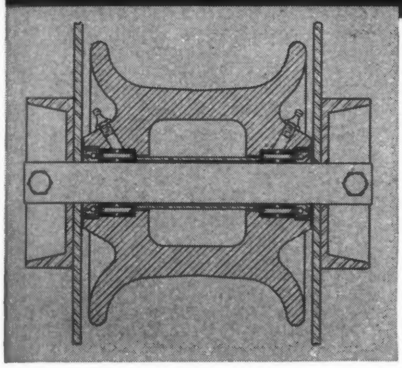
AIRCRAFT and machine tool industries will be interested in the new improved aviation type universal joints recently announced by the Dix Mfg. Co., 603 East Fifty-fifth street, Los Angeles. There are approximately fifteen standard sizes available. Hub diameters of the joints range from



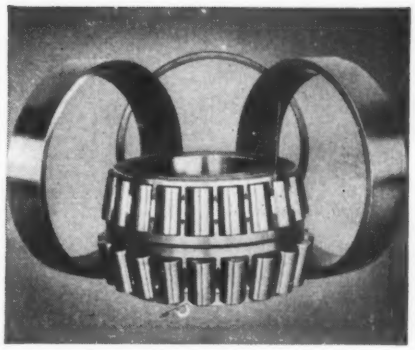
⅜-inch to 4 inches, and approximate weights are from 5/100 of a pound to full 31 pounds each. Special alloy steel, ground to meet Army, Navy and Air Corps requirements, is used in the joints. The hub joints are pin-riveted for aircraft requirements. Because of the new design and construction of the

(*Continued on Page* 136)



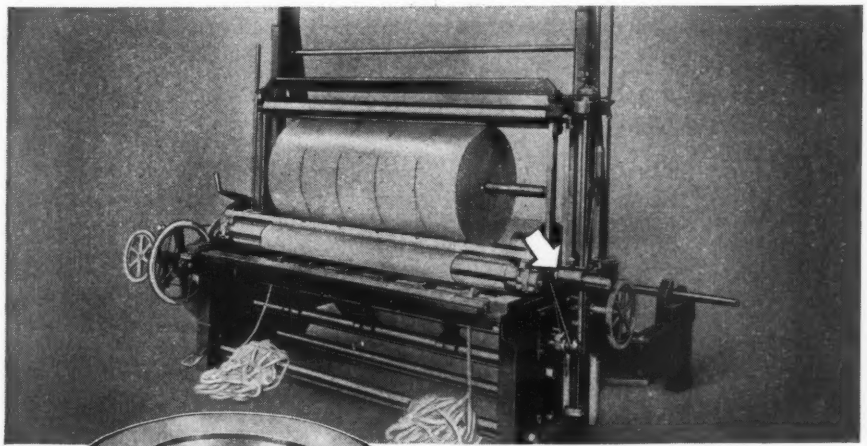


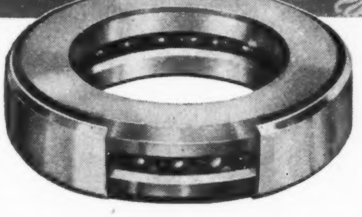
MECHANICAL "STEVEDORES" like this 5-ton STEVE-KRANE built by Silent Hoist Winch & Crane Co. are playing an important part in speeding the loading of goods and equipment for distant fronts. And Bantam Quill Bearings on the boom sheaves and rollers (shown in cross-section view) contribute to the efficiency of these cranes, because of their low coefficient of friction, high load capacity, and effective method of lubrication—while their unit construction facilitates assembly. For full details on these compact anti-friction bearings, write for Bulletin B-104.



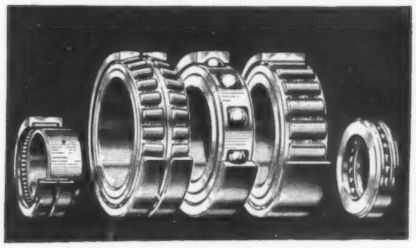
38" O.D., 21" I.D., 19½" LONG, this two-row tapered roller bearing for steel mill service is a typical instance of Bantam's skill in the design and manufacture of large bearings for special jobs. To meet the needs of America at war, Bantam today is manufacturing some of the largest anti-friction bearings ever built.

METALLURGICAL CHECK-UP is a regular part of Bantam inspection on bearings of all types. Here the grain structure of rollers and races is undergoing microscopic examination to assure conformity to metallurgical specifications.





FAST, ACCURATE SLITTING of paper is the job of the Camachine 8, Model 10, product of Cameron Machine Company. Among the factors in the popularity of this machine in paper mill finishing rooms and converting plants is the use of Bantam Ball Thrust Bearings.



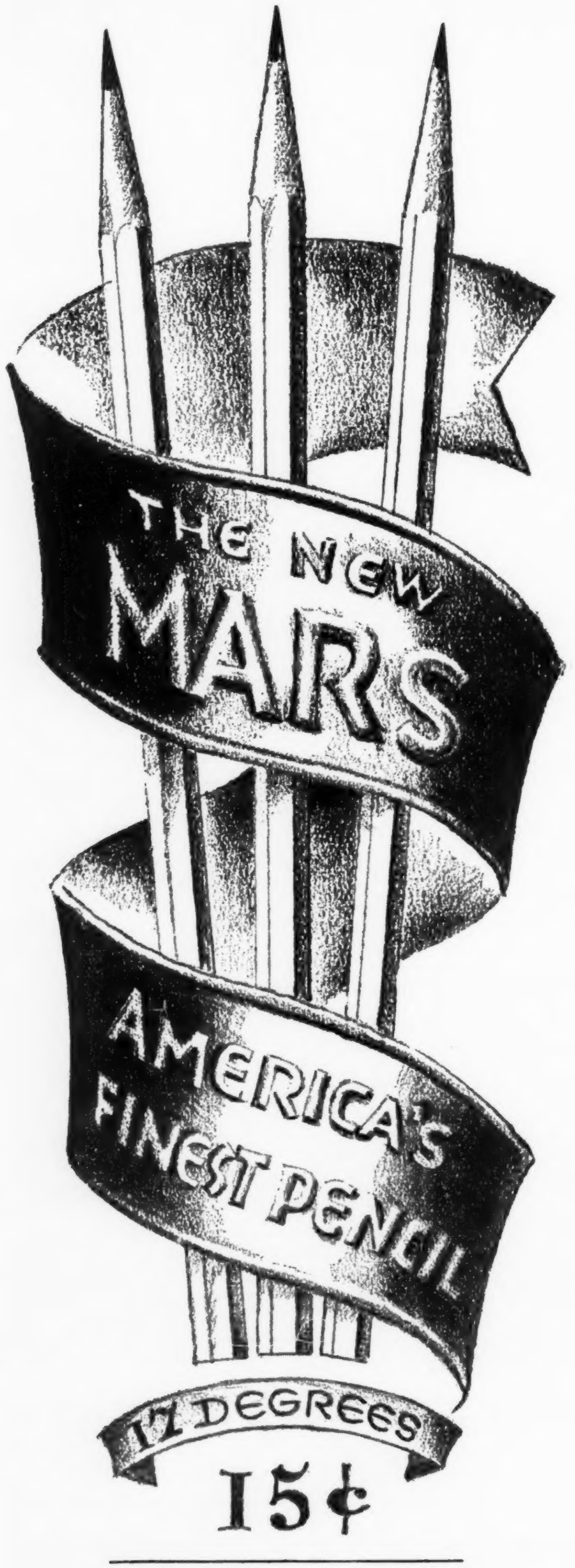
ENGINEERING COUNSEL based on the design and application of straight roller, tapered roller, needle, and ball bearings is a vital phase of Bantam's service to industry. If you are seeking competent advice on your anti-friction bearing problems, TURN TO BANTAM.

ARMY E NAVY

BANTAM BEARINGS

STRAIGHT ROLLER · TAPERED ROLLER · NEEDLE · BALL

BANTAM BEARINGS CORPORATION · SOUTH BEND · INDIANA
SUBSIDIARY OF THE TORRINGTON COMPANY · TORRINGTON, CONN.



(*Continued from Page* 130)

joints, they are said to operate at a large angle, and will function in actual service with rigid and dependable performance.

Oil Window Unit for Visibility

AN OIL window unit for convenient indication of oil level when it is installed in a built-in oil-reservoir casting has been made available by Bijur Lubricating Corp., Long Island City, N. Y. Consisting of a window of clear plastic assembled in a polished metal housing, the unit is furnished in sizes to give a clear window diameter of ⅝, 1 and 1¼-inch, respectively. Preassembly of the unit effects economy in

manufacturing and installation. A special oilproof synthetic gasket insures oiltightness between window and frame. Two holes in the metallic background give easy passage to the oil. Utilizing the assembly tool illustrated, the oil window unit may be pressed into a reamed hole in the machine casting, providing that the casting wall thickness is ¼-inch or more. A thin coat of an oilproof sealing material applied to the surface of the reamed hole makes the installation oiltight.

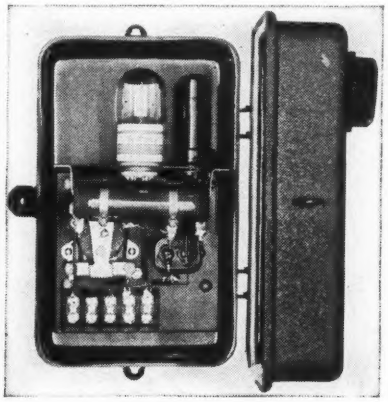
Free-Machining Steel

DEVELOPED by W. J. Holliday & Co., Indianapolis, is a patented process low-carbon open-hearth case-carburizing steel known by the tradename of Speed Case. It was made to meet the need for a steel with the machinability of S.A.E. 1112 and X1112 bessemer screw stock, and the strength of such open-hearth steels as S.A.E. 1020, X1020, X1314 and X1315. A few of the uses of this steel are: Bearing plates, bolster plates, cleaning-machine parts, gears, etc. Speed Treat, a medium-carbon open-hearth steel manufactured under the same general requirements as Speed Case, but with high carbon content, is used for bearing plates, gears and whales, dippers, grab buckets, etc.

Photoelectric Controls Improved

DEVELOPMENT has been completed of a new series of photoelectric controls, according to a recent announcement made by Photoswitch Inc., 19 Chestnut street, Cambridge, Mass. These photoelectric controls, known as Type A15, embody relay contacts designed to handle heavier loads

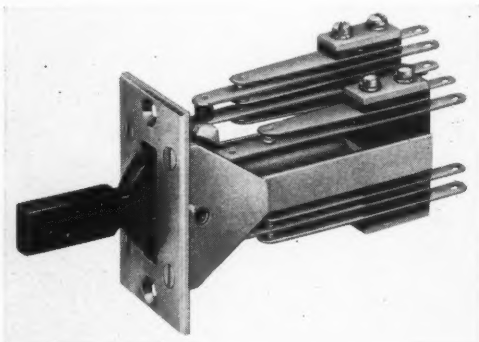
directly, and are conservatively rated at 10 amperes alternating current at 115 volts. Output terminals are those of a single-pole double-throw switch, for either normally closed or normally open operation, providing for action either when the light beam is broken or when it is made. Operating range



of the control is 20 feet with light source L30, and 40 feet with source L60. Type A25 is supplied with light source L30 for 50-foot operation, and with L60 for 100-foot operation. Type A15 is for automatic control of such standard industrial applications as counting, conveyor control, signal and alarm systems, motor or valve control, inspection and break detection, as well as for many specialized processes.

Lever Switch for Aircraft Use

PRIMARILY designed for use in aircraft, radio, communication, annunciator and fire alarm systems, testing apparatus, and a wide range of industrial applications, a new O-42 lever switch has been developed by Donald P. Mossman Inc., 6133 North Northwest Highway, Chicago. A large, well-formed handle permits a firm grip of the hand. The switch has posi-



tive action-locking, nonlocking (spring return to neutral position) and no-throw stops. Construction and materials used in the switch make the unit rugged and light in weight. The maximum rating for this switch is 5 amperes, 110 volts, alternating current (noninductive). It is available in an almost unlimited series of combinations of contact assemblies.

Extruded Tubing and Rods Offered

MANUFACTURED from cellulose acetate butyrate, Tulox TT tubing has been made available by Extruded Plastics Inc., New Canaan avenue, Norwalk, Conn. It can be furnished

AMERICA'S SECRET WEAPON

One of the most powerful guns in the arsenal of America is technical proficiency. Keeping this fact foremost, Perkins concentrates the energies of a considerable engineering and research staff on the problem of improving the mass production of precision gears, and adapting them to new uses. That there may be more efficient airplane engines—better power transmission for all mechanized war equipment, and smoother performance of all those peacetime products in which gears are an integral part, the Perkins organization will continue to apply itself to technical proficiency.

PERKINS PRECISION, CUSTOM-CUT GEARS

help power American Planes

PERKINS MACHINE & GEAR COMPANY, SPRINGFIELD, MASS.

"Throw Your Scrap Into The Fight"

in a full range of standard sizes from 3/16-inch to 2 inches outside diameter. This seamless transparent plastic tubing will withstand considerable pressure, depending upon the internal diameter and wall thickness. An outside diameter of 1 inch x .62-inch wall has withstood 500 pounds per square inch, and ⅜-inch outside diameter x 1/16-inch wall thickness, 1200 pounds per square inch. The tubing may be coiled or otherwise bent to shape by heat and chilling. Tulox HR (hollow rod) is available in round, hex and knurled rods, up to a maximum of 1¼ inch, for screw machine parts, unions, couplings and other parts, which may be machined at about the same speed as brass. Another type of material, Tulox S, is furnished in tubing which is flexible and supplied in coils.

Coolant Strainers Introduced

COOLANT strainers applicable to turret lathes, screw machines, milling, drilling and other metal-cutting machinery using a coolant flow, have been introduced by Metex Textile Corp., 4 Central avenue, Orange, N. J. The unit will strain metal cuttings and chips remaining in suspension, permitting only chip-free solution to pass through the coolant pump where most of them lodge. Each drop of coolant fluid passes through layer on layer of uniform knitted and crimped mesh. In the case of large coolant tanks where a heavy flow of coolant fluid is required, several strainers are "ganged" on a larger intake line. Several sizes of the coolant strainer are available. The size adaptable to most machines—Model "C" —has overall dimensions of 5 inches in diameter, 4 5/32-inch (including nipple) in height, ¾-inch pipe and nipple, and has a capacity up to 10 gallons per minute. Model "D" is somewhat larger and has the straining surface of "C" for deep, narrow sump tanks. Its capacity is 20 gallons per minute.

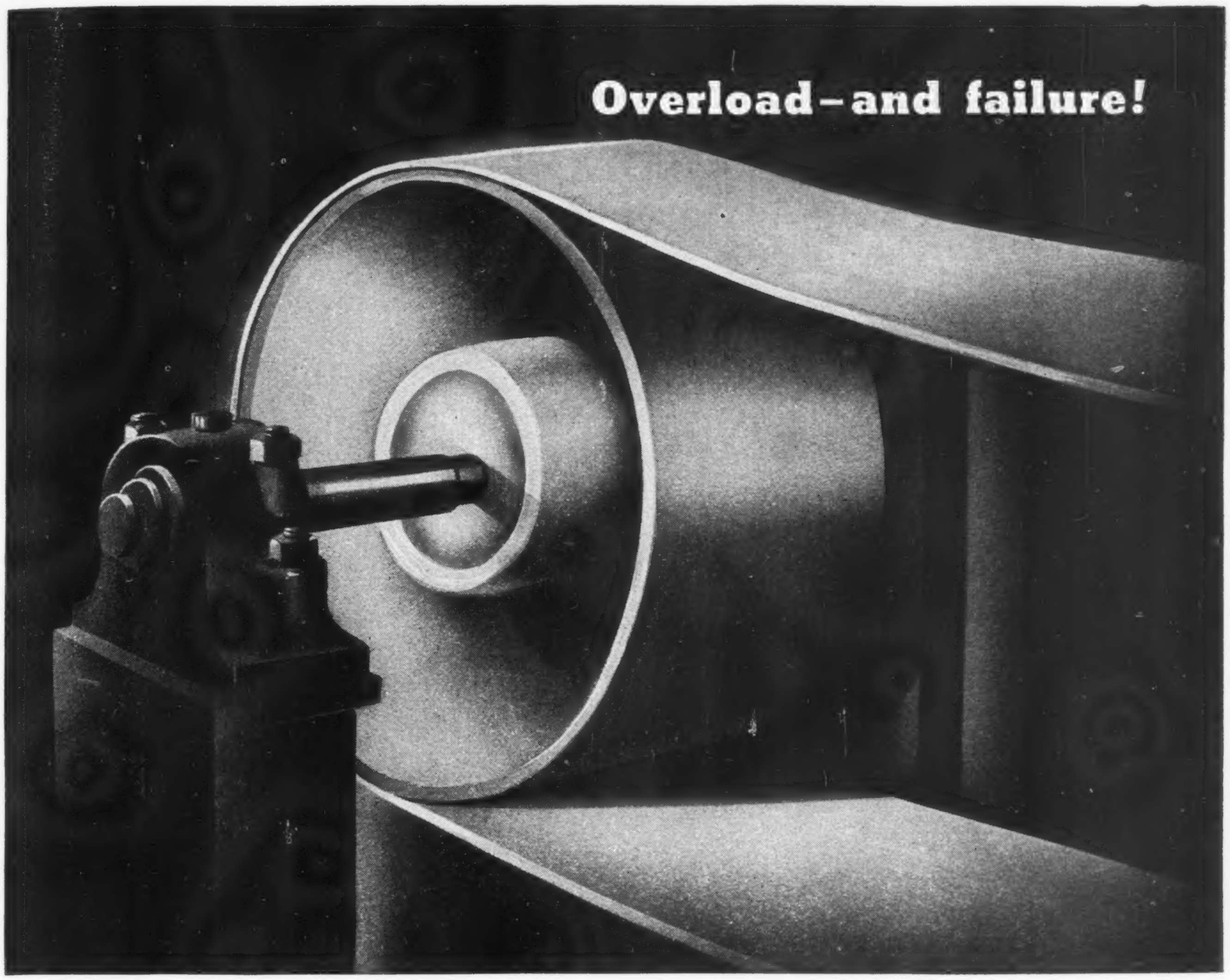
Cold-Forged Thumb Screws

SHOULDER thumb screws are a recent addition to the standard line of The Ohio Nut & Bolt Co., 600 Front street, Berea, O. Made in one piece, the wide-wing, cold-

forged screws have shoulders with the same diameter as a lock washer. They are available generally in the following threads: 10-24, ¼-20, 5/16-18, ⅜-16, ½-13, in ⅝ to 4-inch lengths.

Variable Resistors Are Sealed

RECENTLY announced by the Stackpole Carbon Co., St. Marys, Pa., are two new closed-cover, sealed variable resistors to meet today's demand for units which will perform favorably under intensely humid or dusty conditions, and in either standard radio or high-frequency equipment. A leakage resistance for Type MG on the order of 300 meg. after 48 hours in 95 per cent humidity at 40 degrees Cent. is obtained in the new design. Spacing of current-carrying parts is greater and surface insulation of the molded base is several times that of previous laminated-base units. Furnished with a dustproof cover, Type LP is effectively sealed with a special compound to the point where resistivity from current-carrying parts after 48 hours of 95 per cent humidity at 40 degrees Cent. is five times that of the previous open construction units.



Information supplied by an Industrial Publication

Recent tests by a well-known rubber company prove that as little as three pounds extra tension on power transmission belting, above recommended tension, will shorten its life as much as 68 percent!

In the tests three grades of the present wartime construction of transmission belting were used. Each belt was run at 15 pounds per inch per ply, a 720 pound total for the tension, the recommended figure, and at 18 pounds per inch per ply, a total of 864 pounds tension, on 4 inch diameter pulleys. Belts were all 6 inches wide, 30 feet long, spliced in 10 foot endless lengths. Tests were all highly accelerated.

Belt No. 1 ran for 95 hours before breakdown under the 19 pound tension, and increased its life to 230 hours before failure when the tension was 15 pounds.

Belt No. 2 ran for 88 hours at the 18 pound tension, and for 263 hours before failure at 15 pounds.

Belt No. 3 ran for 15 hours under 18 pound tension, and the service life before failure jumped to 48 hours under the 15 pound tension.

Close attention to "details" like this will save costly shut-downs and increase productive man-hours. This is just another case of designing to meet requirements – another important conservation measure.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.
MOLYBDIC OXIDE BRIQUETTES • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"

MOLY

Climax Molybdenum Company
500 Fifth Avenue · New York City

PROFESSIONAL VIEWPOINTS

" . . . contrary to fact and theory"

To the Editor:

September issue of MACHINE DESIGN contained Part I of an article "Practical Aspects of Bearing Design" by E. B. Etchells and A. F. Underwood. It is believed that certain statements in this article are contrary to accepted fact and theory, and that the conclusions reached by the authors relative to partial bearings contradict their statements made a little earlier.

Particular attention is called to "the best way to lubricate a bearing is by means of a circumferential groove" and "axial grooves are believed to serve no useful purpose that cannot better be served without them." "The same is true of diagonal grooves and of recesses or pockets at the parting lines." However, the authors state "the partial bearings have run three times as long as the 180-degree bearings and are still in perfect condition." No credit is given for the axial space between bearing pads for the introduction of lubricant. In the so-called 180-degree bearing unless at least one axial groove at a point of low pressure is provided, how is the lubricant to be led from the circumferential groove to the surfaces in the loaded area? Do not the axial spaces between bearing pads in the partial bearings constitute grooves for the ready introduction of lubricant to the leading edge of the pad?

Such eminent authorities on the subject of lubrication as Howarth, Karelitz, Bradford, have contributed the results of their findings on the question of oil grooves and where they should be located. It seems to the writer that the above-quoted statements are in direct conflict with the facts and experimental results of these authorities.

Some distinction should be made with reference to running clearance. A bearing with ample clearance may require only one axial groove to obtain sufficient distribution of the lubricant, whereas a bearing with very small clearance requires longitudinal grooves to feed several axial grooves, or the circumference may be divided into several pads, the separations between pads providing axial grooves as noted by the authors under partial bearings.

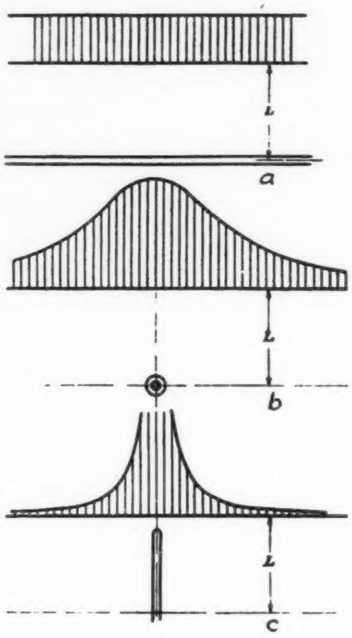
—M. S. GJESDAHL
Landis Tool Co.

" . . . referred to pressure-fed bearings"

To the Editor:

The comments expressed by Mr. Gjesdahl were read with much interest. We presume these comments were made relative to bearing designs with gravity, drip, or ring oil feed, and unidirectionally loaded. Our remarks on grooving were with respect to pressure feed, and nearly all our work in recent years has been with this type. Graphical representation of calculations on the relative flow characteristics between flat plates on three different groovings are shown in the accompanying chart, where *a* represents a circumferential groove, *b* a central hole and *c* an axial groove. In particular, our remarks on circumferential grooving were qualified as to its weakness, and it is of course true that very little lubricant, if any, can be introduced from the groove into the loaded area of the bearing. However,

on the unloaded side this type of groove distributes the lubricant evenly over the surface right down to the loaded area. On revolving loads, of course, the entire surface receives evenly distributed flow. It may be that in certain drip or gravity-feed bearing designs some particular types of grooving could be



advantageously used, especially when speeds and loads are low. When speeds and loads are relatively high, some forced flow must be provided to carry away the friction heat or the life of the bearing will be greatly impaired.

With reference to the tests on partial bearings and the 180-degree bearing, these tests were made on the machine as described under *Fig.* 5, on page 76 of the October issue of MACHINE DESIGN. Forced feed lubrication was used with a single hole on the unloaded side of the journal. This system presents forced flow over the bearing surface similar to the circumferential groove. Some tests with partial bearings have been made with splash lubrication, i.e., depending on the axial spaces between them, but this was found unsatisfactory at high loads and speeds.

The subject of running clearance as far as partial bearings are concerned is well known and it is also known that partial bearings (less than 180 degrees) may be run with no clearance. Our tests were made with clearance in accordance with accepted theory. Integral partial bearings such as referred to by Mr. Gjesdahl have not as yet been shown to be as satisfactory as the unit type.

—EUGENE B. ETCHELLS
Research Laboratories Div.
General Motors Corp.

" . . . alternative sources of Supply"

To the Editor:

Thanks for publishing such a fine reference as the "Directory of Materials" contained in your October issue. In today's attempt to get useful supplies and materials, new friends must be made and it is often difficult to locate alternative sources of supply. Your October issue is, therefore, a welcome addition to my files.

—R. S. ELBERTY
T. W. & C. B. Sheridan Co.

MEN OF MACHINES

FOR fourteen years vice president and for the past year executive vice president, William C. Carter has been elected president of Link-Belt Co., Chicago, succeeding Alfred Kauffman who has resigned because of ill health. A mechanical engineering graduate of the University of Illinois, Mr. Carter joined the Link-Belt Pershing Road Chicago plant organization as a draftsman in 1902. He has consecutively held the positions of engineering department supervisor, construction superintendent, and plant superintendent. He has also been executive vice president in charge of production. Since Mr. Kauffman's illness Mr. Carter has been executive vice president in complete charge of the affairs of the company.

Dr. Edwin Howard Armstrong, professor of electrical engineering, Columbia university, has recently been awarded the Edison Medal by the American Institute of Electrical Engineers "for distinguished contributions to the art of electric communication, notably the regenerative circuit, the superheterodyne, and frequency modulation".

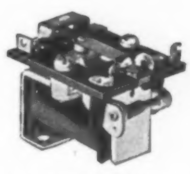
Harry Hall has been appointed chief engineer of the Engine division, Worthington Pump & Machinery Corp., Buffalo, N. Y.

Carl G. Preis, formerly chief engineer, has been elected vice president in charge of engineering, American Can Co. He is also vice president and general manager of Amertorp Corp., a wholly-owned subsidiary corporation engaged in the manufacture of naval and aerial torpedoes.

J. Y. Scott, president, Van Norman Machine Tool Co., Springfield, Mass., and A. G. Bryant, vice president, Cleereman Machine Tool Co., Green Bay, Wis., have been named directors of the National Machine Tool Builders association. They will complete the unexpired terms of George H. Johnson and John S. Chaffee, who resigned to become director and deputy director, Tool division, War Production Board.

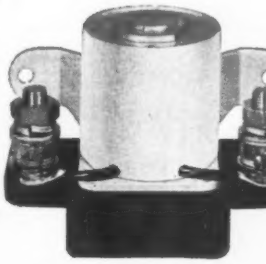
Richard E. Palmer, formerly in the aircraft division of the War Production board, has been appointed assistant to O. L. Woodson, vice president and assistant general manager of the Bell Aircraft Corp. Following his graduation he worked as an engineer for the Vernille Aircraft Corp., and from 1930 to

★ **From conveyor belts that shuttle goods, foot by foot, along assembly lines . . . to giant cargo planes that span wide continents and seas with loads of war material . . . each presents a successful job of current control achieved with "Relays by Guardian." For instance . . .**



Series 195 Relay

THE SERIES 195 MIDGET RELAY has numerous aircraft and industrial applications and is one of the smallest relays ever made. It's smaller than a match box, yet sturdy enough to withstand more than 20 times gravity in acceleration tests. Weighs less than an ounce! May be equipped with coils for operation up to 75 volts and will handle double pole, double throw contact combinations. Write for Series 195 Bulletin.



B-4 Solenoid Contactor

THE B-4 SOLENOID CONTACTOR is used for starting motors in cargo planes, for turret control in bombers. It's a 24-volt, single pole contactor rated at 200 amps continuous, 1,000 amps surge. It withstands acceleration exceeding 10 times gravity; operates from sea level to 40,000 feet, from —60°F to +170° F. In the same class are types A-3 (12 volts, 200 amps continuous), B-5 (24 volts, 50 amps continuous), B-6 (24 volts, 100 amps continuous), B-7 (24 volts, 200 amps continuous). All built to U. S. Army Air Force specifications. Send for B-4 Bulletin for further details on these units.

Planning for the future? Our wartime experience can help you build better peacetime products.

GUARDIAN ELECTRIC

1601 WEST WALNUT STREET CHICAGO, ILLINOIS

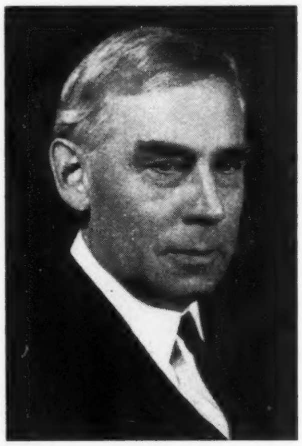
A COMPLETE LINE OF RELAYS SERVING AMERICAN WAR INDUSTRY

1932 was assistant chief engineer of the Stinson Aircraft Corp. He then joined Curtiss-Wright as engineer in the propeller department.

William Floyd Beasley, formerly principal automotive engineer, U. S. Army, Ordnance Department, Washington, is now chief engineer of the Tank and Motor Transport Development Branch, Army Ordnance department, Washington.

Edward Schmotzer has become connected with the National Advisory committee for Aeronautics, Engine Research Laboratory, Cleveland, as assistant electrical engineer.

Robert E. Hartsock has recently been transferred by J. I. Case Co. to the Gun Mount division with responsibility for engineering on antiaircraft equipment in five plants.



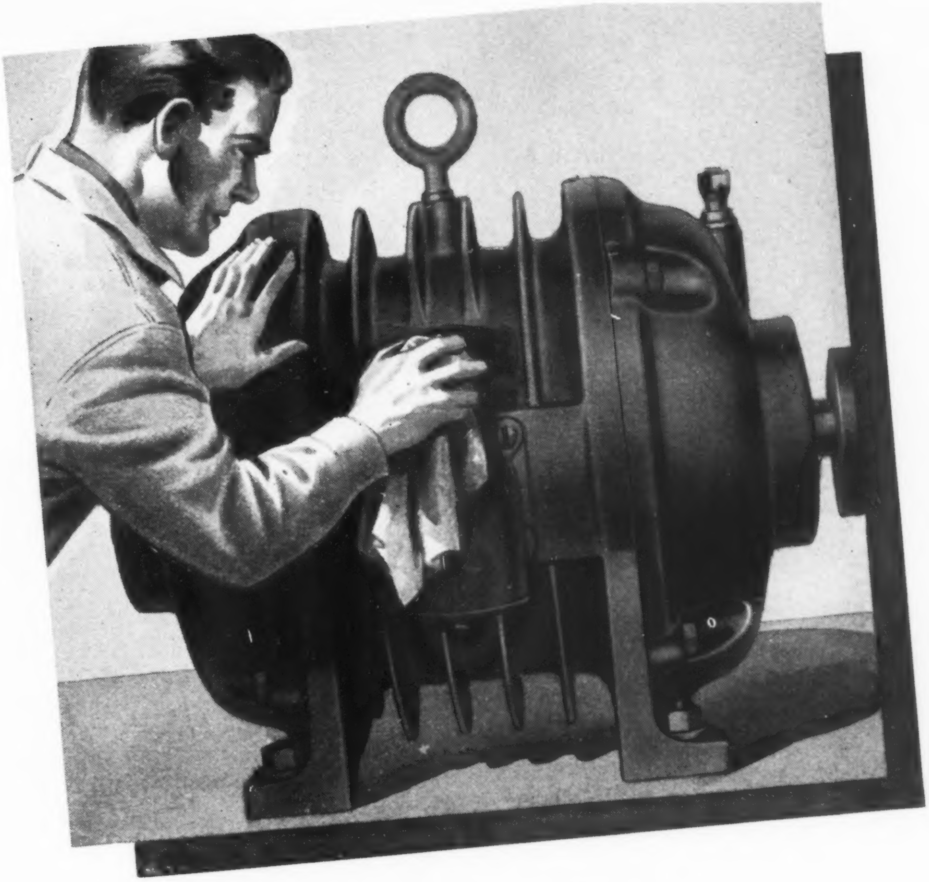
Widely recognized as an authority on thermodynamics, Harvey N. Davis has been named head of the Office of Production Research and Development, War Production Board. Mr. Davis has been president of Stevens Institute of Technology for some time, and is a past-president of the American Society of Mechanical Engineers. Born at Providence, R. I., in 1881, he graduated from Brown University in 1901 with an A.B. degree and in 1903 and 1906 respectively was awarded A.M. and Ph. D. degrees by Harvard university. He began his teaching career at Brown immediately following graduation. From 1904 to 1910 he was an instructor at Harvard and later became assistant professor of physics. In nine years he was made professor of mechanical engineering at Harvard, serving until his election as president of the Stevens institute in 1928.

Charles E. MacDonald, design engineer at Menasco Mfg. Co., Burbank, Calif., has been appointed acting project engineer with Kinner Motors Inc., Glendale, Calif.

Wilfred E. Bettoney has been made test engineer at the Dodge Chicago plant of Chrysler Corp. Prior to this appointment he had been assistant mechanical engineer, U. S. Army Air Corps, Materiel division, Wright Field, Dayton, O.

Hans Bohuslav has joined the Sterling Engine Co. of Buffalo as vice president in charge of engineering. He also held this position with Enterprise Engineering company before joining the Sterling company.

T. P. Wright, aeronautical expert and vice president of the Curtiss-Wright Corp., has been elected an honorary fellow of the Royal Aeronautical Society. This honor has been accorded to only 15 of the society's membership. Dr. Jerome Hunsaker,



Is There *HORSEPOWER* Asleep In Your Warehouse?

You may or may not be able to take advantage of this suggestion, but we believe it is worth passing along on the off-chance.

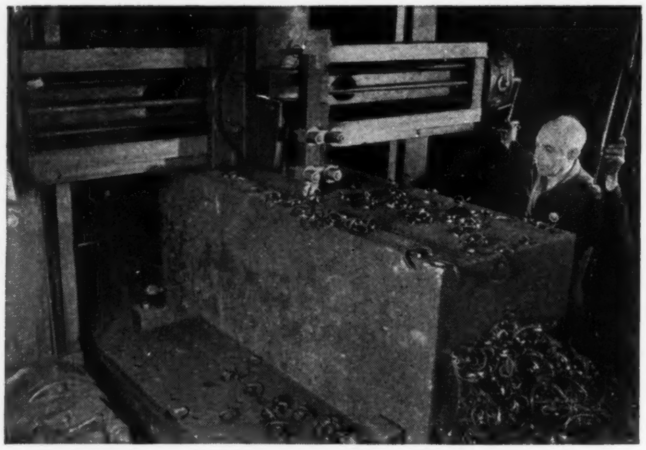
Make a thorough examination of the machine tools you have had to lay up in your warehouse because of drastic changes in your production program. They may well be a source for motors to power your new machines, on order or on hand, that are being kept out of action by unavoidable delays in motor delivery. If you can find motors of the right horsepower and type to meet your present requirements, put them to work on your war production.

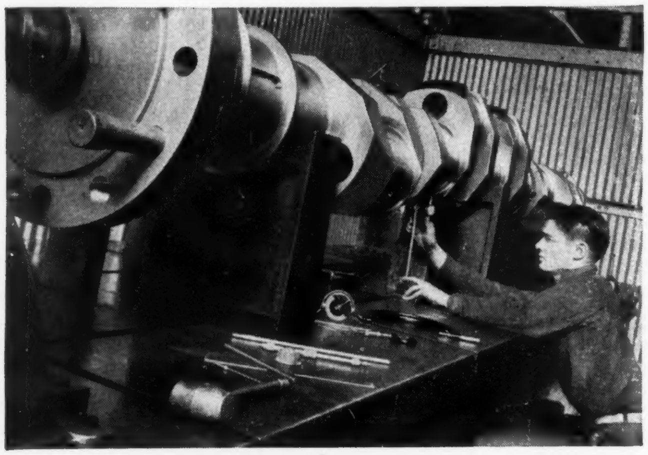
We are building Delco motors to the limit permitted by critical material shortages. While we do everything possible to fill orders for new Delco motors, make use of your "veteran" motors.

DELCO MOTORS

DELCO PRODUCTS DAYTON, OHIO

DIVISION OF GENERAL MOTORS CORPORATION





professor of Aeronautics at the Massachusetts Institute of Technology, and ORVILLE WRIGHT, pioneer aeronautical engineer, also have been awarded the honor.

WALTER O. WILL has become associated with Tools Inc., Chicago as president. He resigned as chief engineer of Service Tool Die & Mfg. Co., Chicago.

ALFRED SONNTAG, formerly chief engineer of Riehle Testing Machine division of American Machine & Metals, has joined the staff of the testing machine department of Baldwin-Southwark division of Baldwin Locomotive Works, Philadelphia.

DONALD E. CRESSEY, who has been aeronautical engineer, Douglas Aircraft Co. Inc., Santa Monica, Calif., has been transferred to the El Segundo plant as aeronautical engineer.

JOEL M. GOOCH has joined the Guiberson Diesel Engine Co., Dallas, Tex., as engineering draftsman in the research department. He had previously been connectd with Menasco Mfg. Co., Burbank, Calif.

JOHN S. RICHARDS has been appointed director of research at American Steel & Wire Co., Cleveland. FLINT C. ELDER, formerly director of research, is now research engineer on special assignments from the vice president.

M. E. FIRST, who has been chief engineer of C. O. Bartlett & Snow Co., has been appointed director of the foundry equipment department of the company. Mr. First is a director of the company and has been chief engineer for the past twenty-two years.

C. H. MATHEWSON has been elected president of the American Institute of Mining and Metallurgical Engineers. He is chairman of the department of metallurgy at Yale university.

ELLSWORTH L. MILLS, vice president, Bastian-Blessing Co., has been elected president of the International Acetylene association. GLENN O. CARTER, consulting engineer, The Linde Air Products Co., is vice president.

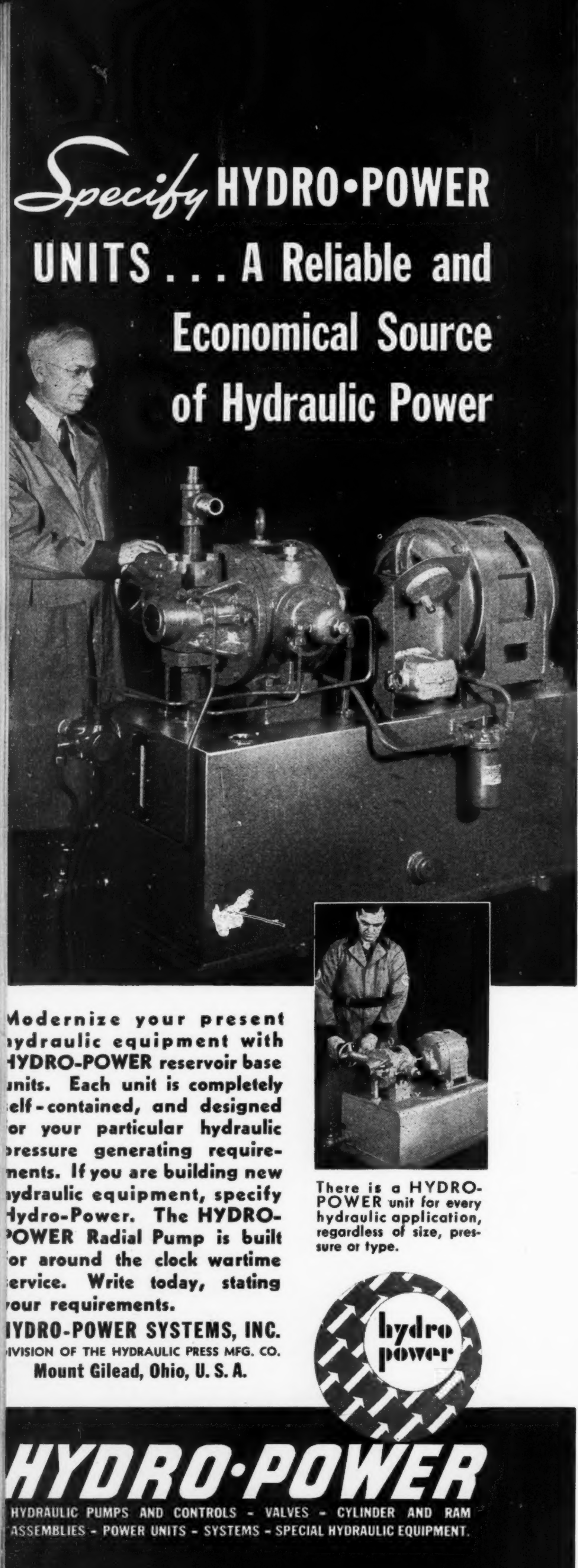
E. A. ROSS, formerly associate professor, Industrial Education, in charge of aeronautics, Santa Barbara State College, has joined the staff of Utah State Agricultural college, Logan, Utah, as professor of aeronautics and head of the department.

EUGENE J. MANGANIELLO has been promoted from associate mechanical engineer to mechanical engineer, National Advisory Committee for Aeronautics, Langley Field, Hampton, Va.

MARY LEE MARQUIS has become connected with General Electric Co., Schenectady, as an engineer in the aircraft and marine department.

FRANK M. KINCAID JR. has been promoted from assistant project engineer to project engineer of Wright Aeronautical Corp., Paterson, N. J.

JOHN ROSEVEAR, who has been an engineer for twenty years with Westinghouse, has been appointed staff assistant in the in-



dustrial engineering and equipment department of Westinghouse Lamp division, Bloomfield, N. J.

EWALD J. WOLFF is now assistant head of the mechanical engineering department No. 6, of the Research Laboratories division of General Motors Corp., Detroit. He formerly had been an engineer with this company.

LEO EDELSON, for the past ten years development engineer for Handy & Harman, has joined the Induction Heating Corp. as executive vice president.

PAUL P. BAUERNSCHMID has left his position as chief designer with Chandler-Evans Corp., South Meriden, Conn., to become design engineer for Waterbury Tool division of Vickers Inc., Waterbury, Conn.

GEORGE L. MITSCH has become connected with the Eastern Aircraft Trenton division of General Motors Corp. to work on special assignments, particularly in the conservation of critical materials.

SYDNEY J. WATERS, previously research project engineer at Northrup Aircraft Inc., is now consultant, aircraft division, Willys-Overland Motors, Toledo, O.

JOHN H. SIPCHEN, previously vice president in charge of engineering, sales and production for Manufacturers' Equipment Co., has been named first assistant to the president of Anker-Holth Mfg. Co., Chicago. He will have charge of the development of air and hydraulic chucks, among other duties.

AUSTIN HILLER, formerly metallurgical engineer, Planning and Utilities division, Pittsburgh Ordnance district, is now process development engineer, Remington Arms Co. Inc., Bridgeport, Conn.

J. L. BENNETT of Hercules Powder Co. has been elected president of the American Institute of Chemical Engineers.

JOHN R. RAMSON JR. has joined Glenn L. Martin Co. Baltimore, as engineer. He formerly was apprentice engineer, Carnegie-Illinois Steel Corp.

PETER F. HURST, formerly general manager of the Aeroquip Corp., Jackson, Mich., has become consulting engineer of Michigan Patents Corp., of the same city.

J. E. D. MCCARTY has been made chief research engineer, Simmonds-Benton Mfg. division, Vergennes, Vt. He formerly was with Firestone Tire & Metal Products Co.

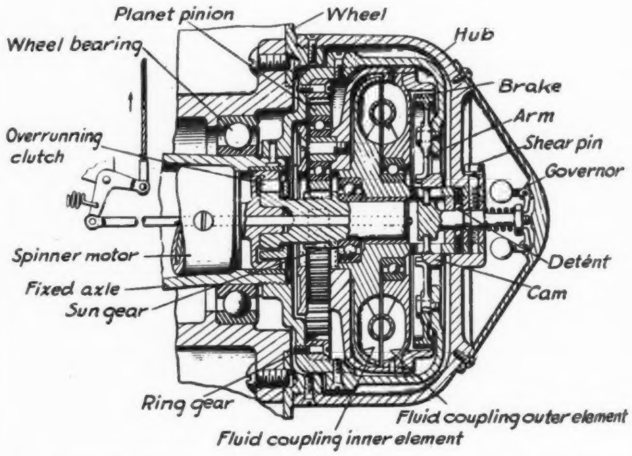
LIEUT. P. W. BAKARIAN, previously connected with Dow Chemical Co., is now with the Experimental Engineering section, Materials division, Wright Field, Dayton, O.

U A. PATCHETT has been transferred from the engineering department of Chrysler Corp., Highland Park, Mich., to the new aircraft engine company, the Dodge Chicago plant, where he is engineer in charge of production tests.

NOTEWORTHY PATENTS

Controls Airplane Landing Wheel Speed

LARGE tires on airplane wheels take severe punishment when the plane lands, due to the fact that they must acquire, from rest, a speed of rotation corresponding to the landing speed of the ship. The wheels, having a large moment of inertia, are forced to slip for some time before reaching the proper speed and considerable rubber is stripped or burned off at each landing, especially on concrete runways. A design providing means to start the wheels rotating prior to landing and also to furnish a smooth braking action during the landing run is covered by patent 2,298,523, assigned to Bendix Aviation Corp.



Fluid coupling transmits power from spinner motor to wheels, also serves as brake during landing run

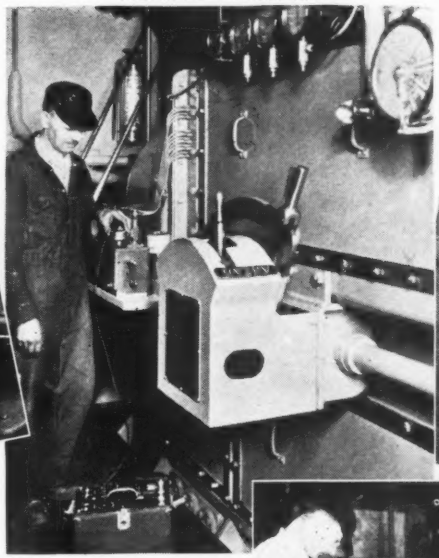
Each wheel is mounted on an antifriction bearing supported by the fixed axle, as shown in the illustration. Power for rotating the wheels prior to landing is furnished by a spinner motor mounted inside the hollow axle and driving the sun gear of a planetary unit through an overrunning clutch. Ring gear of the planetary unit is attached to the fixed axle, while the planet pinions are mounted on pins attached to the outer element of a fluid coupling. Inner element of the coupling is secured to the wheel hub by a shear pin as shown.

When the plane is about to land, the spinner motor is energized and drives the wheel through the planetary unit and the fluid coupling, the outer element of which is the driver in this case. At the moment when the landing gear reaches fully extended position just prior to the wheels touching the ground, a circuit breaker connected with the landing gear interrupts the current to the motor. Wheel speed at the instant of contact with the ground is somewhat less than that corresponding to the landing speed and the subsequent run further accelerates the wheels. The overrunning clutch permits the spinner motor to stop and the wheels to speed up.

At a predetermined maximum wheel speed centrifugal

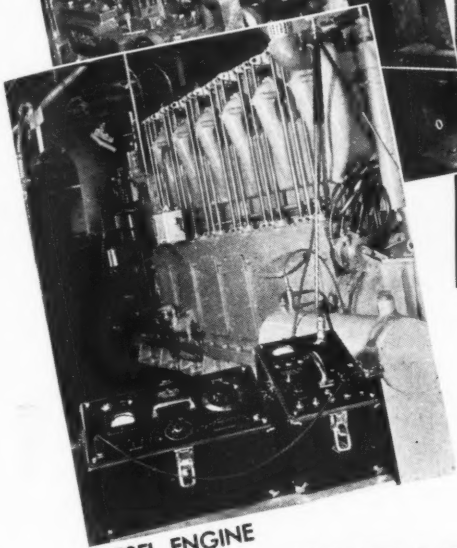
SCREW MACHINE

FISHING TRAWLER

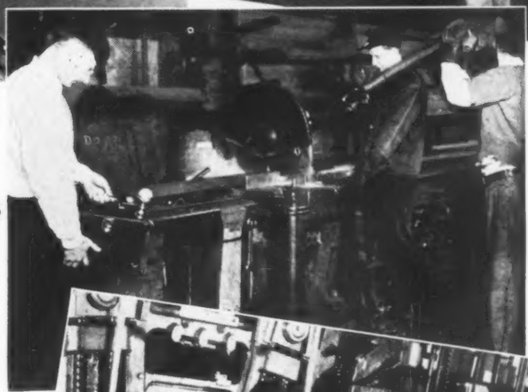


AIRPLANE

DIESEL ENGINE



CUTTING SAW



PRINTING PRESS

PUNCH PRESS

NOISE and VIBRATION

BOTH ARE IMPORTANT factors affecting the operation of mechanical equipment. When their magnitudes exceed certain predetermined limits, usually based on experience, they are symptoms of misalignment, incorrect adjustment, excessive wear, or possibly faulty design or manufacture.

Hundreds of the country's leading manufacturers of mechanical equipment use General Radio noise and vibration meters* as aids to design, production and inspection. These instruments are simple, compact, accurate and easy to use.

As a further aid to mechanical engineers interested in noise and vibration measurements, we are publishing in our monthly magazine, the General Radio EXPERIMENTER, a series of articles on the principles and procedures involved. A request on your company letterhead will bring these articles to you each month as they are published.

ASK FOR BULLETIN NO. 830

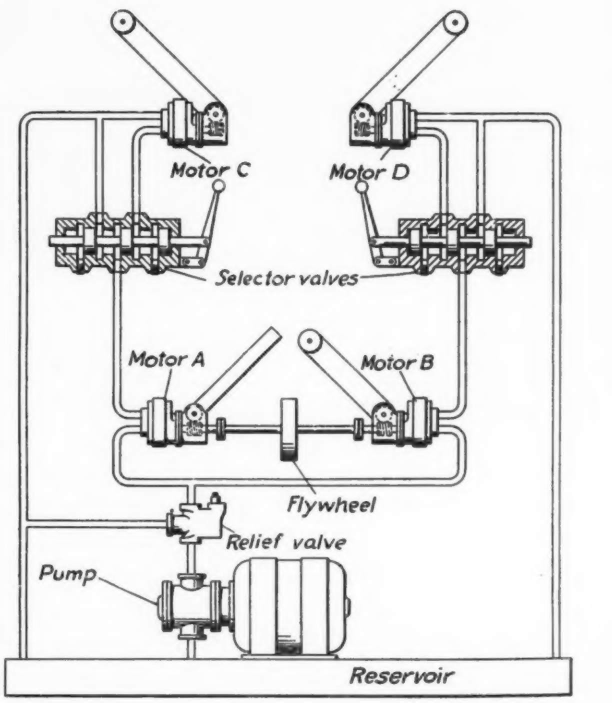
*Because all our facilities are devoted to war projects, these meters, at present, are available only for war work.

GENERAL RADIO COMPANY · Cambridge, Massachusetts

action on governor weights overcomes the resistance of a governor spring and engages a brake through a cam and lever mechanism. The brake locks the outer element of the fluid coupling to the fixed axle and the coupling then functions as a fluid brake exerting a decelerating effect on the wheel and plane. The brake is prevented from releasing itself as the speed drops by a spring-loaded detent which registers with a groove in the brake control spindle when in the braked position. To release the brake after the plane has come to rest, tension applied to a cable terminating in a handle in the cockpit presses the release rod against the brake control spindle, displacing the detent and allowing the spindle to move outward. During take-off the spindle is held in the outward position to prevent reapplication of the brake as the wheels gain speed.

Multiple Hydraulic Drive

WHERE hydraulic power transmission is applied to machines which have a number of separate driven elements it is often advantageous to employ a single pump supplying several fluid motors. With motors connected in parallel the circuit acts as a differential gear, delivering power to whichever motor carries the lightest load. Series connection, on the other hand, maintains a fixed speed ratio between the motors but imposes a pressure on the pump which is the sum



Four driven elements maintain fixed speed ratio with free interchange of load

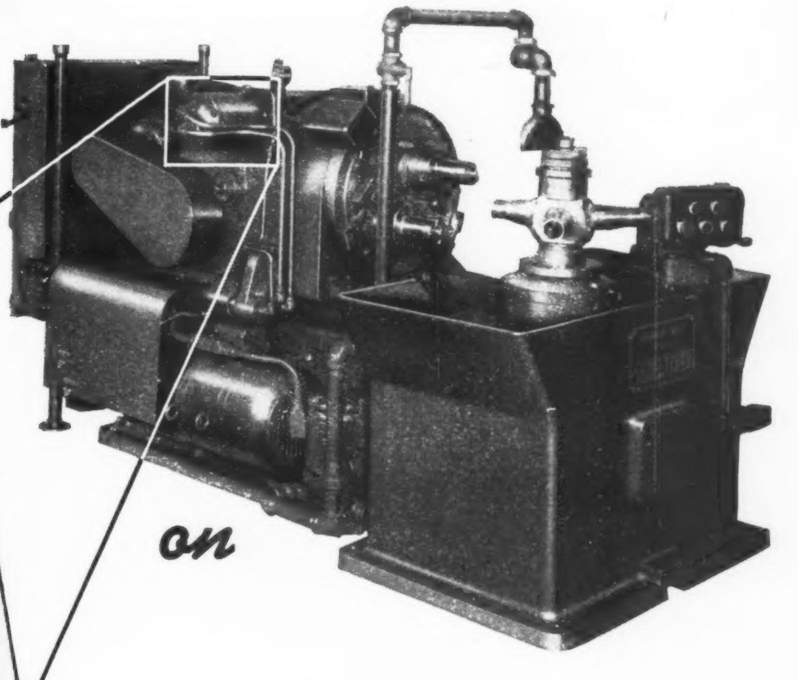
of pressure loads on all motors. A circuit for multiple drive in which these objections are overcome, permitting a definite speed ratio and free interchange of load, is the subject of patent 2,301,098, assigned to Vickers Inc.

Pump discharge passes through a relief valve and is delivered to motors *A* and *B* which are in parallel. Each drives a separate section of the machine and the speeds of the two are synchronized by a connecting shaft carrying a flywheel. Outlet from each motor leads to a selector valve from which fluid may be conducted either to another motor or back to the reservoir.

In operation with the selector valves in the positions illus-

RBC NEEDLE BEARINGS

help speed war production



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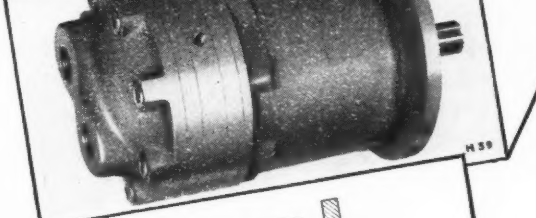
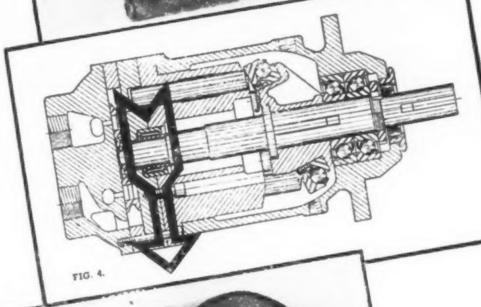




SUNDSTRAND Hydraulic Units

Milling the curved surfaces of airplane propellor hub spiders is speeded up by the use of a Sundstrand Fluid Motor which rotates the head on the milling machine shown above. Sundstrand says in part, "All of the parts (of the motor) are designed for precision manufacture to exceedingly close limits. Friction between moving parts is negligible . . . "

Here then is a logical application for RBC CYCLOPS Bearings, anti-friction type carrying heavy radial loads and occupying minimum space. It is a self-contained bearing with a one piece through hardened and ground outer race encasing a full complement of rollers. An oil groove in the race eliminates the necessity of grooving the housing while a snap ring channel makes it easy to locate and secure the bearing in the housing.

On any problem affecting the application of roller bearings to any type of machinery or industrial equipment, call on RBC engineers.

ROLLER BEARING CO. of AMERICA
TRENTON . . . . NEW JERSEY

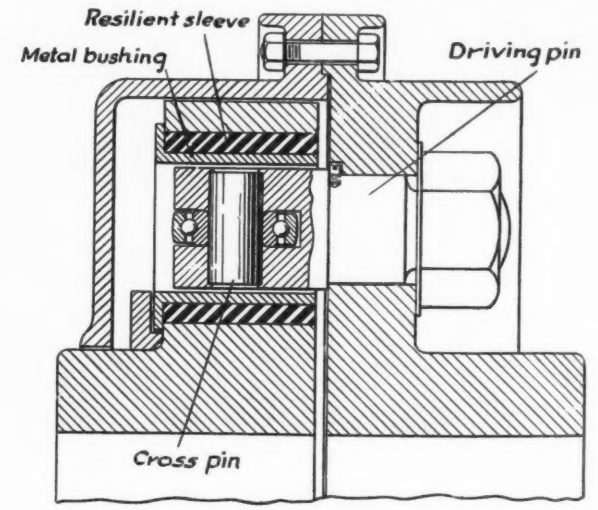
trated, motors *A* and *B* are driven at a speed determined by the pump speed, and discharge to the reservoir. Discharge from each is proportional to its displacement. Since both motors operate at the same pressure differential, the power delivered by either motor may be either wholly or partially used in driving the mechanism to which it is immediately connected, the connecting shaft serving to transfer surplus power from one to the other as needed.

When the left-hand selector valve, for example, is shifted, diverting the discharge from motor *A* through motor *C*, the latter starts up and imposes a high back pressure on motor *A*. The momentary decrease in output of motor *A*, however, is made up by the absorption of energy from the flywheel, thus preventing overload on the pump. Motor *D* is brought into operation in a similar manner. As the relative loads on the different fluid motors vary, a heavily loaded motor may be assisted by a lightly loaded motor so long as the total load on the system is within the capacity of the pump.

Permits Frictionless Axial Movement

WHEN a flexible coupling which permits axial freedom with minimum friction is required, the design covered by patent 2,296,955, assigned to Mather & Platt Ltd., offers a solution.

As shown in the illustration, driving pins secured in one flange of the coupling extend into metal-bushed sleeves of rubber or other resilient material assembled in the opposite flange. Fitted into the end of each coupling pin within the



Antifriction bearing mounted in driving pin permis free axial movement between coupling halves

sleeve is a cross pin on which is mounted a ball bearing. Spherical outer race of the bearing and bore of the metal bushing have a slight clearance which permits rolling freely whenever axial movement occurs. The resilient sleeves provide the necessary freedom in directions other than the axial.

COMPRISING a standard Slotmaster and an ingenious indexing mechanism for slotting the teeth on clutch jaws, a special machine has been built by the Hoover Tool & Die Co. and the Experimental Tool & Die Co. Built-in master cam feeds the part against the special slotting tool by means of an indexing ratchet operated by the main shaft. Thus the slotting strokes are synchronized with the movement of the master cam. The machine completes the cycle automatically and the finished part is an exact duplicate of the master cam.

ASSETS to a BOOKCASE

Engineering Mechanics

By B. B. Low, lecturer in mechanical engineering, Military College of Science (Great Britain); published by Longmans, Green & Co., New York; 252 *pages,* 5½ *by* 8¼ *inches, clothbound; available through* MACHINE DESIGN, $4.50 *postpaid.*

Dealing mainly with kinematics and dynamics, this book will appeal to design engineers because of its straightforward presentation and concise style, although written primarily as a college text. Beginning with an introduction to velocity and acceleration and their representation by vectors, the book continues with a discussion of the use of velocity vector diagrams and instant centers, analytical solutions of velocity and acceleration problems, graphical solutions, force, torque, work, energy, dynamical similarity, simple harmonic motion, analysis of cams, motion of rigid bodies, vibration, and deflection of beams.

Calculus is freely used in the analytical discussions, thus overcoming an objection to many of the texts written for use in this country. The latter too often cover the subject inadequately because of the apparent attempt to avoid calculus.

It is of interest to note that three generations of Lows have participated in the book. Originally inspired by the author's father D. A. Low, well known as the author of "Applied Mechanics" to which this book is a companion volume, the text and problems have been completely checked by his son, E. D. Low, who also worked out the answers to the 172 practice problems included.

□ □ □

Plastics for Industrial Use

By John Sasso; published by McGraw-Hill Book Co. Inc., New York; 229 *pages,* 6 *by* 9 *inches, clothbound; available through* MACHINE DESIGN, $2.50 *postpaid.*

Recognition of plastics as engineering materials, entitled to consideration as such on their own merits rather than simply as alternates, is producing the inevitable crop of books on the subject. Of these the volume under review, author of which is associate editor of our contemporary, *Product Engineering*, is the latest. Emphasizing throughout the general aspects of plastics application, the book is a thoroughly practical reference for plastics users. In addition to discussion of each of the more important materials, chapters are also included on principles of design and of molding and mold design.

Prepared primarily for the use of engineers in industry, "Die Casting for Engineers" is a comprehensive 148-page book of unusual interest. Sections are devoted to principles and history of die casting machines, alloys for die casting, elements of die construction, application, specifications, inspection, tests, flash removal, machining practice, and jigs and fixtures for machining die castings. The section on alloys includes composition and mechanical properties of the commoner zinc, aluminum, magnesium, copper, lead, and tin alloys used in die casting. Measuring 6 by 9 inches, the book is available from The New Jersey Zinc Co., price $1.00.

How Acceleration Analysis Can Be Improved

(*Continued from Page* 102)

where $[Cp]\ (\omega' - \omega)^2 = V_{pP}^2/[Cp]$, the usual form employed in computations.

This is the relation known as Coriolis' law of acceleration in plane motion. The component $2V_{pP}\omega$ is what is known as the Coriolis component, or the compound supplementary acceleration.

The component $[Cp](\alpha' - \alpha)$ is tangent to the path, in the direction of V_{pP} is V_{pP} is increasing, in the opposite direction if V_{pP} is decreasing. It will be designated by the symbol A^t_{pP}.

The component $[Cp](\omega' - \omega)^2$ is normal to the path, directed from p toward C. It will be designated by the symbol A^n_{pP}.

The direction of the component $2V_{pP}\omega$ depends upon both the direction of V_{pP} and the direction of ω. A good rule to use is the following: Turn the vector V_{pP} 90 degrees about its origin in the direction of ω (clockwise or counterclockwise). The direction in which this vector now points is the direction of the acceleration component $2V_{pP}\omega$, (see *Fig.* 4).

Equation 11 for A_{pP} should be compared with the expression for A_{pC}:

$$A_{pP}=[Cp](\alpha'-\alpha) \mathrel{+\!\!\rightarrow} [Cp](\omega'-\omega)^2 \mathrel{+\!\!\rightarrow} 2[Cp](\underline{\omega'}-\omega)\omega$$

$$A_{pC}=[Cp]\alpha' \mathrel{+\!\!\rightarrow} [Cp]\omega'^2$$

It should be noted that when the body is stationary or has a motion of pure translation, $\omega = O$ and $\alpha = O$, then $A_{pP} = A_{pC}$.

In order to gain an idea of the physical significance of the Coriolis component let us imagine ourselves mounted on non-skid roller skates. The skating rink will be a large disk, or turntable, revolving at ω radians per second in a counterclockwise direction as viewed from above. First let us try skating radially outward from the center of the disk at V feet per second relative to the disk. The effect of centrifugal force tending to increase our speed outward will of course be felt. Also it will be found necessary to lean well to the left to avoid toppling to the right. This second effect is due to the Coriolis component of our acceleration. The situation is illustrated at a in *Fig.* 5. The presence of the component $2V\omega$ can be explained in the following manner. The vector representing our velocity relative to the disk is continually changing direction due to the rotation of the disk at angular velocity ω, giving us an acceleration $V\omega$. Also, since we are moving outward toward a point of higher velocity on the disk, our velocity relative to the ground must increase to avoid skidding to the right. This gives us the second half of the Coriolis component of acceleration.

Now let us attempt skating in a circle of radius R, counterclockwise on the disk, as shown at b. This time only centrifugal force will be felt. Our acceleration will be

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the sum of the components $R\omega^2$ (the acceleration of the point beneath our feet), V^2/R due to the fact that we are traveling a curved path on the disk, and the component $2V\omega$. It will be necessary to lean well toward the center to maintain balance. Again, one half of the Coriolis component is caused by the turning of our relative velocity vector V at rate ω. The second half is due to the fact that the point we are approaching on the disk has a velocity different in direction from that of the point we have just left and our absolute velocity must change accordingly to avoid slipping.

Components Opposed When Direction Reversed

If we reverse direction and travel in a circle clockwise on the disk the situation will be as shown at *c*. Our acceleration will now be made up of the components $R\omega^2$ and V^2/R directed toward the center and $2V\omega$ directed outward from the center. It will not be necessary to lean as far inward to maintain our balance as in the previous example. By skating fast enough we can reduce the resultant force to zero and stand upright. That will occur when $V = R\omega$ and the Coriolis component just cancels the sum $(R\omega^2 + V^2/R)$. In that case we should actually be standing still relative to the earth.

In general, regardless of the path we attempt to follow on the revolving skating rink, we shall always be subject to the acceleration $2V\omega$, one half of which will be due to the changing direction of our relative velocity caused by rotation, and the second half due to the fact that at any instant the point we are approaching has a velocity differing either in magnitude or direction, or both, from that of the point we have just left.

To summarize, the following relations are necessary for the analysis of any mechanism in plane motion:

For any three points:

$$V_{CO} = V_{BO} \mathrel{+\!\!\rightarrow} V_{CB}$$

$$A_{CO} = A_{BO} \mathrel{+\!\!\rightarrow} A_{CB}$$

For two points on the same link:

$$V_{BC} = [CB]\omega$$

$$A_{BC} = A^n_{BC} \mathrel{+\!\!\rightarrow} A^t_{BC} = [CB]\omega^2 \mathrel{+\!\!\rightarrow} [CB]\alpha$$

For two coincident points on different links:

$$V_{pP} = [Cp](\omega' - \omega)$$

$$A_{pP} = A^t_{pP} \mathrel{+\!\!\rightarrow} A^n_{pP} \mathrel{+\!\!\rightarrow} 2V_{pP}\omega$$

$$= [Cp](\alpha' - \alpha) \mathrel{+\!\!\rightarrow} (V_{pP})^2[Cp] \mathrel{+\!\!\rightarrow} 2V_{pP}\omega$$

In the second, and final article several problems will be worked out in detail to show the application of this analysis to the construction of velocity and acceleration polygons.

BUSINESS AND SALES BRIEFS

ELECTION of Edwin Olney Jones as a vice president has been announced by Federal-Mogul Corp., Detroit. Mr. Jones, who also continues as sales manager of the company's original equipment division, has been associated with the company since it was organized in 1924. He has been a director since 1929.

♦

A. R. Abelt, secretary of Baldwin-Duckworth division, has been elected a director to replace F. J. Weschler. In addition to being made a director, Mr. Abelt was also elected a vice president. He joined the Chain Belt organization in 1907 and literally grew up with the company. In 1922 he was made sales manager of the Chain Belt and Transmission division, retaining this position until early in 1942 when he became manager of that division.

♦

In charge of metal sales for The New Jersey Zinc Sales Co. in the Chicago area, D. P. Brannin now becomes district sales manager of the pigment and metal sales division, with headquarters in Chicago. J. P. Dunphy, of the New York sales department, has been made district sales manager, pigment division, with headquarters in New York city.

♦

Appointment of Earl S. Patch as mechanical engineer in charge of application engineering has been announced by Henry L. Crowley & Co., West Orange, N. J., producers of highly specialized materials and parts such as powdered iron cores and steatite or ceramic materials. Mr. Patch was formerly sales manager of the Moraine Products Division.

♦

American Leather Belting association, 53 Park Row, New York, has appointed Roy C. Moore, of Charles A. Schieren Co., New York, as president, George L. Abbott, of Graton Knight Co., Worcester, Mass., as vice president, and Arthur H. Rahmann, George Rahmann & Co., New York, as treasurer.

♦

Formerly eastern manager of Kold-Hold Mfg. Co., Frank A. Haag has been made sales manager, with headquarters in the main office at Lansing, Mich. He succeeds Paul R. Porteus.

♦

Promotion of A. Frank Golick, assistant general manager of sales, to general manager of sales, LaSalle Steel Co., Chicago, has been announced. He joined the company in 1939 as a member of the metallurgical engineering department and became assistant general manager of sales the following year.

♦

Removal of the St. Louis district warehouse from 4063 Forest Park avenue to new and larger quarters at 712 Cass avenue, St. Louis, has been announced by The Carpenter Steel Co., Reading, Pa. Need for the new warehouse has been brought about by increased wartime demands. K. L. Crickman, district manager, will be in charge of the new

warehouse which will also be the headquarters for district representatives, John A. Koch and William I. Potteiger.

In a recent announcement, Celanese Celluloid Corp., New York, has called attention to Celluloid, first plastic introduced in America, marking its seventieth anniversary. No celebration is being planned because the company is hard at work producing this material for war requirements.

Transamerica Corp. has acquired control of Adel Precision Products Corp., Burbank, Calif., aircraft equipment manufacturer. This is the third industrial plant recently taken over by this company. The other companies acquired include the Enterprise Engine and Foundry Co., San Francisco, and Aerco Corp., Los Angeles, producers of aircraft parts.

Completely equipped for producing aluminum castings by a special permanent mold process, a new plant is being put into operation by The Majestic Co., Huntington, Ind. The new company will be known as The Majestic Aluminum Co., and will produce castings of high tensile strength, elongation and finish.

Announced recently is the appointment of William H. Knight as director of sales and market research for the Elastic Stop Nut Corp. Mr. Knight has had twenty years' experience in sales and marketing activities. Formerly he was president of Electric Household Utilities Corp.

According to a recent announcement of The Ohio Seamless Tube Co., Shelby, O., Irving F. Pohlmeyer, west coast sales and service engineer for the company, is now located at Suite 200, 170 South Beverly drive, Beverly Hills, Calif.

James H. Savage of the plastics division of Colt's Patent Fire Arms Mfg. Co. is now plastics consultant of the War Production Board's Bureau of Industrial Conservation, replacing Gus Holmgren, who has gone to the plastics section of the Navy's Bureau of Ordnance.

Keystone Carbon Co., Saint Marys, Pa., has recently appointed George B. Shaw as its sales engineer. He will devote his efforts to the company's negative temperature coefficient resistance material, a recent development of the company.

In charge of Twin Disc-Clutch Co. factory branches at St. Louis, Tulsa and Dallas for the last eight years, John B. Jenkins has been made manager of the Hydraulic division, Rockford, Ill.

Production facilities of the Wright Aeronautical Corp., of Paterson, N. J., have been extended to a vast, newly constructed plant called a "warspeed" factory of concrete "somewhere in New Jersey," according to a recent announcement by M. B. Gordon, vice president and general manager of the company. The new plant will produce engines in the upper horsepower brackets to power combat planes, troop transports and cargo carriers of the United Nations.

With an anticipated monthly production of over 500,000 pounds of castings, the world's largest magnesium foundry is nearing completion in Chicago. The offices of the company, The Howard Foundry Co., will soon be moved to the new headquarters at 4900 Bloomingdale road, according to its pres-

ident, Frank C. Howard. He also made public the recent acquisition of the Aurora Foundry Co., Aurora, Ill., which will handle the production of all the company's brass, bronze and copper castings, and will be known as the bronze division of the Howard Foundry Co. The original foundry now located at 1700 North Kostner avenue will be known as the aluminum division, and will cast that metal solely.

♦

For oven ten years associated with Wilkening Mfg. and most recently in charge of the sales of piston rings for the Wilkening Mfg. Co., Warren K. Lee has been elected vice president, with headquarters in the Lexington building, Detroit.

♦

Election of Max McGraw as president of the National Electrical Manufacturers association, New York, has been announced. Mr. McGraw is president of McGraw Electric Co., Chicago.

♦

Connected with Metal & Thermit Corp., New York, for ten years, Merritt L. Smith has been appointed sales manager. Charles D. Young previously district manager of the company's Chicago office, has been made sales manager of the welding division.

♦

Associated with Driver-Harris Co. since 1907, George A. Lennox, assistant sales manager, has been appointed general sales manager. Joseph B. Shelby has been appointed assistant sales manager. Prior to his appointment Mr. Shelby was manager of the foundry.

♦

Rudolph B. Flershem, formerly general manager, Buffalo Bolt Co., North Tonawanda, N. Y., has been elected president of the company, succeeding Raymond K. Albright who has been named chairman of the board.

♦

Removal to new quarters at 388 Wacouta street, St. Paul, Minn., has been announced by Minnesota Plastics Corp.

♦

Enlarged offices and plant of the Seamlex Co. Inc. makers of flexible all-metal hose, have been completed and the company is now located at these new quarters at 27-27 Jackson avenue, Long Island city, N. Y.

♦

Appointments of J. O. Walz as assistant manager and J. D. Miner as manager of engineering, of Westinghouse Electric & Mfg. Co. have been recently announced by the Westinghouse small motor division at Lima, O. Mr. Walz was formerly manager of engineering and Mr. Miner previously served as aviation section engineer. Both joined the company as graduate students.

♦

At a special meeting of the board of directors of The National Bronze & Aluminum Foundry Co., Cleveland, John L. Schmeller, formerly executive vice president, has been elected president of the company.

♦

Of the newly formed integral-horsepower motor section of General Electric Company's motor division, K. R. Van Tassel has been appointed manager of sales. He became connected with the company as a student engineer, was transferred to the transformer engineering department, later the single-phase motor department of which he became designing engineer, and in 1932, the fractional-horsepower motor engi-

neering department. Since 1940 he has been manager of sales of Lynn Motors group. D. A. Yates has been placed in charge of this latter division, replacing Mr. Van Tassel.

♦

Succeeding C. L. Pratt Jr., resigned, Earl Wesselhoff has been named manager of the Boston branch of Morse Chain Co., Ithaca, N. Y. He has been transferred from the company's Detroit plant where he started twenty-two years ago.

♦

For more than twenty-five years connected with Continental Roll & Steel Foundry Co., East Chicago, Ind., in various capacities including sales, George B. Wadlow has been made assistant to the president of the Continental Ordnance Corp., a subsidiary of the Continental Roll company.

MEETINGS AND EXPOSITIONS

February 11-12—

The Engineering Institute of Canada. Fifty-seventh annual general meeting to be held at Royal York, Toronto, Canada.

February 12-13—

Steel Founders' Society of America. Annual meeting to be held at Edgewater Beach hotel, Chicago. Raymond L. Collier, 920 Midland building, Cleveland, is secretary.

February 14-18—

American Institute of Mining and Metallurgical Engineers. Annual meeting to be held at the Engineering Societies building, New York. Frank T. Sisco, 29 West Thirty-ninth street, New York, is secretary.

March 1 5—

American Society for Testing Materials. Spring meeting and convention to be held at the Statler hotel, Buffalo, N. Y. R. E. Hess, 260 South Broad street, Philadelphia, is assistant secretary.

March 25-27—

American Society of Tool Engineers. Annual meeting and Machine and Tool Progress exhibition to be held in the Milwaukee auditorium, Milwaukee. Clyde L. Hause, 2567 West Grand boulevard, Detroit, is national secretary.

April 7-10—

Electrochemical Society. Meeting to be held in Pittsburgh. Colin G. Fink, 3000 Broadway, New York, is secretary.

April 20-23—

National Electrical Manufacturers' association. Spring meeting to be held at the Palmer House, Chicago. W. J. Donald, 155 East Forty-fourth street, New York, is managing director.

April 26-28—

American Society of Mechanical Engineers. Spring meeting to be held in Davenport, Iowa. C. E. Davies, 29 West Thirty-ninth street, New York, is secretary.

April 28-30—

American Foundrymen's association. Forty-seventh annual meeting to be held at Hotels Jefferson and Statler, St. Louis. R. E. Kennedy, 222 West Adams street, Chicago, is secretary.

...TIRED - but NOT "EXHAUSTED"

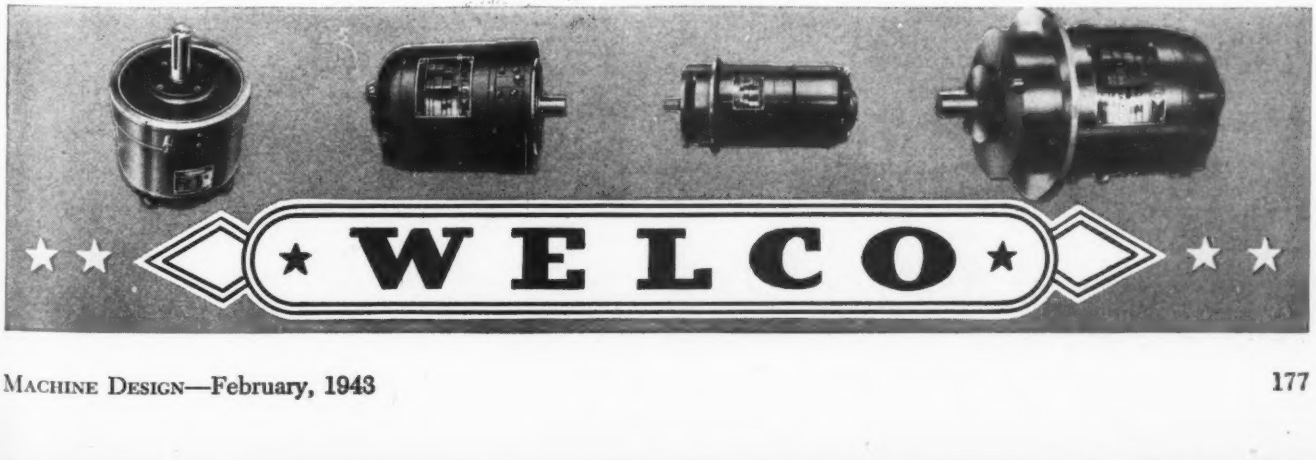
No red leather—no chrome trim—they're built for business—these landing barges of our armed forces.

But the lounge of a luxury liner has never supplied purer air than that breathed by our boys crowded around the fuming diesel engines of these small craft.

Ventilation must be sure. Not for comfort, but for life itself. When it was decided that no ordinary motor could be depended upon to power the vital exhaust fans necessary, Welco was called on to build the special water-proof, drip-proof motors that would not fail.

In war or peace, when a *special* motor is needed, look to Welco.

THE B. A. WESCHE ELECTRIC CO.
1626 Vine St. **Cincinnati, Ohio**



NEW MACHINES—

And the Companies Behind Them

(For illustrations of other outstanding machinery, see Pages 116-117)

Air Conditioning

Self-contained, cyclone-type dust collector, Aget-Detroit Mfg. Co., Detroit.

Dust collector, Torit Mfg. Co., St. Paul, Minn.

High-velocity fume exhauster, General Blower Co., Chicago.

Armament

Loading and unloading bomb-cleaning machine, Pangborn Corp., Hagerstown, Md.

Annealing machine for steel cartridge cases, Morrison Engineering Corp., Cleveland.

Double-end centering machine for gun forgings, etc., Kent-Owens Machine Co., Toledo, O.

Heavy-duty tapping machine for aircraft, tank, and shell production, Cleveland Tapping Machine Co., Cleveland.

*Ambulance, Henney Motor Co., Freeport, Ill.

*Automatic shell-coating machine, DeVilbiss Co., Toledo, O.

Finishing

Grinding and buffing machine, Standard Electric Tool Co., Cincinnati.

Infra-red dryer for polishing wheels, Park Chemical Co., Detroit.

Small-sized block sanders, National Air Sanders Inc., Rockford, Ill.

General purpose superfinishing machine, Foster Div., International Machine Tool Corp., Elkhart, Ind.

Parkerizing unit, N. Ransohoff Inc., Cincinnati.

Mechanical parts cleaner, Practical Products Co., St. Paul, Minn.

Metal-cleaning revolving drum, Colts Patent Fire Arms Mfg. Co., Hartford, Conn.

Metal parts washer, Sturdy-Built Equipment Corp., Milwaukee.

Metal-washing machine, Magnus Chemical Co., Garwood, N. J.

Heat Treating

Forced convection furnace, Lindberg Engineering Co., Chicago.

Special furnace, Johnson Gas Appliance Co., Cedar Rapids, Ia.

Electric furnace for small metal parts, Thermo Electric Mfg. Co., Chicago.

Atmosphere furnaces, Delaware Tool Steel Corp., Wilmington, Del.

High-temperature fans for furnaces, Despatch Oven Co., Minneapolis.

Flame type mouth and taper annealing machine, Morrison Engineering Co., Cleveland, Ohio.

Heat-treating temperature control unit, Upton Electric Furnace Div., Detroit.

Instruments

Spark plug testing machine, Denison Engineering Co., Columbus, O.

*Magnetic inspection machine, Western Industrial Engineering Co., Los Angeles.

*Automatic frequency response recorder, Sound Apparatus Co., New York.

Materials Handling

Heavy index milling machine, Blank & Buxton Machinery Co., Jackson, Mich.

Hydraulic arbor press, Studebaker Machine Co., Chicago.

Hydraulic bending and beveling machine, Hufford Machine Works Inc., Redondo Beach, Calif.

Pinion and gear-cutting machine, Waltham Machine Works, Waltham, Mass.

Specially designed hollow mill, Le Maire Tool & Mfg. Co., Dearborn, Mich.

Electric pedestal grinder, The Lima Photo Engraving Co., Lima, O.

Hydraulic bulldozer, Beatty Machine & Mfg. Co., Hammond, Ind.

Horizontal and vertical milling machine, Lombard Governor Corp., Ashland, Mass.

Single purpose thread milling machine, Hill-Bartlett Machine Co., Rockford, Ill.

*Double-action toggle drawing press, E. W. Bliss Co., Brooklyn.

*Special 3-way metalworking machine, Baker Bros. Inc., Toledo, O.

*Bar jig mill, De Vlieg Machine Co., Detroit.

Universal cutter and tool grinder, Covel Mfg. Co., Benton Harbor, Mich.

Turret lathe, Morey Machinery Co. Inc., New York.

Shear, O'Neil-Irwin Mfg. Co., Minneapolis.

Transportation

*Steam locomotive, Baldwin Locomotive Works, Philadelphia.

(*Illustrated in pictorial spread, Pages 116, 117)